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The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1959

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

1st October 1958 to 30th September 1959

COMMONWEALTH MYCOLOGICAL INSTITUTE
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THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-SEVENTH YEAR)

1959

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The correct abbreviation of the title of this Report is :—
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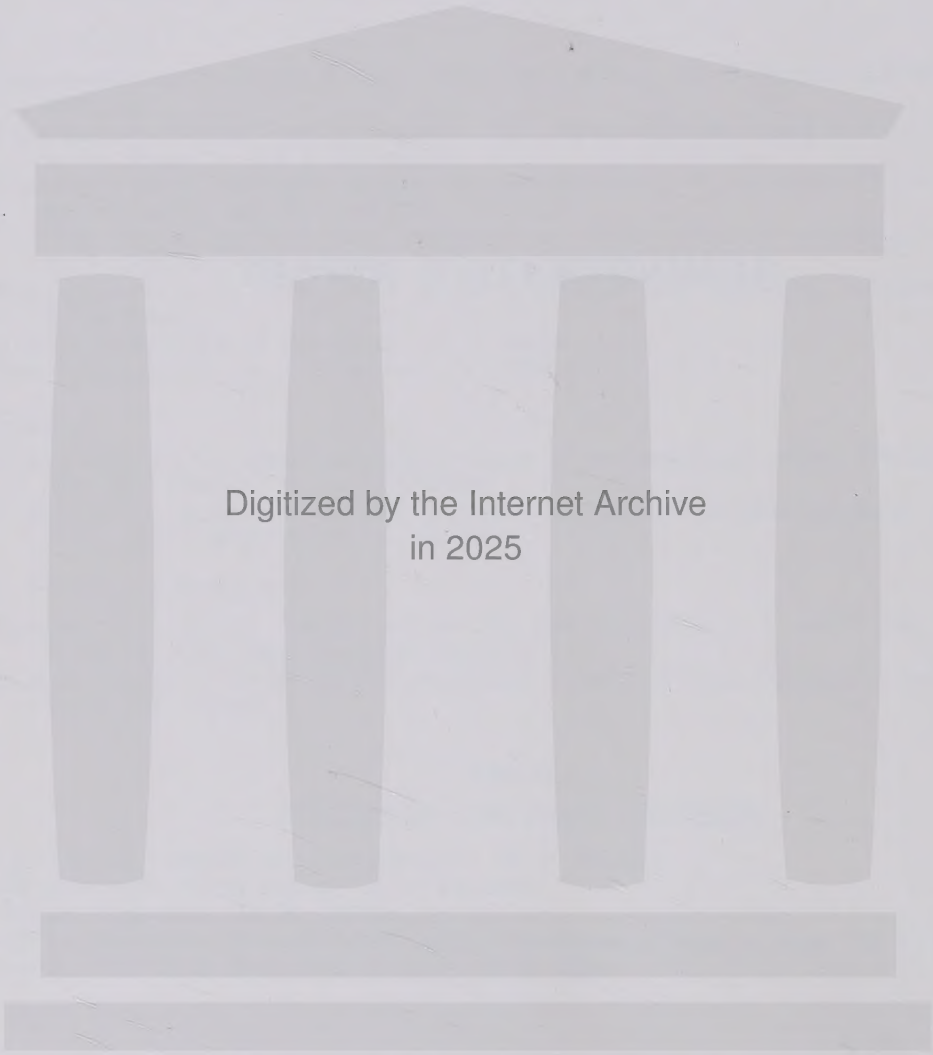

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ADMINISTRATIVE REPORT

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Appointed by the Council of the Royal Society:

Professor T. A. BENNET-CLARK, Ph.D., F.R.S., University of London, King's College, Department of Botany, 68 Half Moon Lane, London, S.E.24.

Appointed by the Governors of Wye College, Kent:

B. S. FURNEAUX, M.Sc., 94 Warwick Park, Tunbridge Wells, Kent.
D. SKILBECK, C.B.E., M.A., Wye College, Wye, Kent.

Appointed by the Research and Advisory Committee of Wye College, Kent:

Professor H. W. MILES, D.Sc., Ph.D., Wye College, Wye, Kent.

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K. S. Dodds, D.Sc., Ph.D., John Innes Horticultural Institution, Bayfordbury, Hertford, Herts.

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F. A. Secrett, C.B.E., F.L.S., V.M.H., Hurst Farm, Milford, near Godalming, Surrey.

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C. R. Favell, Cardinals, Lewes Heath Orchards, Horsmonden, Kent.

Appointed by East Malling Research Station:

F. R. Tubbs, M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

Appointed by the Staff Council of East Malling Research Station:

Miss E. M. Glenn, B.Sc. (*Appointed May* 1959).

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F. R. Tubbs, M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

The Representative of the Staff Council:

Miss E. M. Glenn, B.Sc. (*Appointed May* 1959).

Co-opted Members:

Professor G. E. Blackman, M.A., F.R.S., Department of Agriculture, University of Oxford.
Professor W. O. James, M.A., Ph.D., F.R.S., Imperial College of Science and Technology, Department of Botany, South Kensington, London, S.W.7.
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Captain R. Wellington, M.C., Colescus, Gorran Haven, St. Austell, Cornwall.

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(1st October, 1959)

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* Recognized Teacher of the University of London.

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P. B. HALDENBY.†

† New appointment 1958-9.

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† New appointment 1958-9.
‡ Field records: also attached Entomology and Plant Protective Chemistry.

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C. H. W. Slater.

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Photographer: E. Yoxall Jones.

Assistant (Scientific):

Mrs. B. M. Eaton (*née* Smith).

* Recognized Teacher of the University of London.

† New appointment 1958-9.

‡ Also **Fruit Storage Investigations** (in collaboration with Ditton Laboratory).

FARM STAFF

Superintendent of Field Experiments : F. H. VILLIERS, M.Sc.Agric.Econ., B.Sc.Agric.(Reading), N.D.A.

Assistant Plantations Officer: Miss B. F. SEYMOUR.

Experimental Nurseries : H. R. J. BYFORD.

Experimental Greenhouses : M. M. MACNEILL, M.Sc.(Lond.), C.D.H.(Glas.).
A. TIDY.
M. COLE.

Bradbourne Gardens : Miss K. GREENSTREET.

Workshops : G. G. M. WELLER.
F. A. KING.
A. C. WHYATT.†

Farm Staff with twenty-five years' service :

C. BATES, B.E.M. (44).
J. DENYER (39).
E. WENHAM (39).
H. CRITTENDEN (36).
E. HAYES (36) (*Caretaker*).
W. HENSON (35) (*Fruit Foreman*).
W. JENNER (33).

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Assistant to the Secretary : W. J. CLARKE.†

Director's Personal Secretary : Mrs. R. COOK.

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F. DALY.
Miss C. J. MOORFIELD.†
Miss S. HORROCKS.†

Housekeeper : Miss A. M. C. BOOTH.

† New appointment 1958-9.

THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, East Malling Research Station.

STAFF

Director : G. K. Argles,† Dip.Hort.(Wye), A.I.C.T.A.

Consultant Director : F. R. Tubbs, M.Sc.(Lond.), Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

Assistant Director : G. E. Tidbury,† B.Sc.(Lond.), A.R.C.S., A.I.C.T.A.

Assistants : V. H. Goldschmidt, Ph.D.(Berlin).
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Miss P. J. Rowe-Dutton, B.Sc.Hort.(Lond.).
Mrs. E. Ulyatt, Dip.Hort.(Eisgrub).
Miss E. M. J. Napier, B.Sc.Hort.(Lond.).

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NATIONAL AGRICULTURAL ADVISORY SERVICE

Accommodated at East Malling Research Station

Telephone : West Malling 2418.

REGIONAL FRUIT ADVISORY OFFICER, SOUTH-EASTERN REGION

F. A. Roach, B.Sc.Hort.(Reading).

Clerical Assistant : Mrs. D. Nye. (*Part-time.*)

† New appointment 1958-9.

GENERAL DEVELOPMENT AND ACTIVITIES

The meat of the Annual Report for most of those who receive it is undoubtedly in those parts which together make up the Research Report. The results reported therein depend on much organization and many happenings which are set on record in this Forty-seventh Administrative Report of the Executive Committee, for those who are interested in the ' workings ' as well as the ' finished product '.

In each year there is generally some highlight to report. In 1959, the achievement of the Trustees of the Development Fund in acquiring land adjoining the Station overshadows all else. The new land is sufficient to keep the Station in a state of vigorous animation for the next quarter century and will eventually bring up the total acreage available to 500. In this purchase, the Trustees have had the full support of the Association.

Most of the income of the Station comes from the State through the Agricultural Research Council. This support for our enterprises is invaluable, but in the long run it is the fruit industry itself that can best make the fruits of that support ' come alive '. East Malling grew out of the industry, which has come to its aid on many occasions since Jesse Amos came from Wye to start work on the 20-acre Great East Field in 1913. How far the industry continues to foster the child that it conceived will be clear from the ensuing pages.

Obituary

To visitors to East Malling in the twenties, especially at hop picking time, Professor E. S. Salmon was a familiar figure and he was closely concerned with the development of the Station in the early years, being an honorary member of the Executive Committee until 1935. We much regret to record his death in October 1959.

Likewise, we must record the death in September of Mr. L. J. Cook, who represented the Horticultural Trades Association from 1930 to 1957, and was well known at East Malling, especially on the Plant Prices Sub-committee.

Sir Ian Heilbron, whose death was reported in the same month, represented the research fund committee of the Institute of Brewing for only three years (1954-7) ; nevertheless, during that time his advice on scientific problems was very valuable and we were sorry that his many other commitments dictated his retirement.

Governing Members

In the second year since their appointment we are glad again to have few changes to report on the Governing Body. We were pleased to hear of Mr. J. M. S. Potter's recognition by the Royal Horticultural Society in the award of the V.M.H., and the inclusion of his name in Her Majesty's Honours List for January 1960 is yet another cause for gratification.

During the year, Mr. A. P. Preston was succeeded by Miss E. M. Glenn as Representative of the Staff Council, after serving for three years. We should like to take this opportunity of thanking Mr. Preston for his services, for this appointment is by no means a sinecure.

Twenty Governors attended the special day arranged for them on 24th June. They visited a large part of the Research Station land and discussed its experimental use and treatment. They were also shown developing lines of research on the effects of magnesium on growth and cropping of apples, the selection of quince rootstocks for pears, and soil-borne and leaf-hopper transmitted virus diseases of soft fruit.

Trustees of the Development Fund

Lord Selborne has been a Trustee since the Development Fund was started in 1928 and Chairman since 1944. We were indeed sorry, particularly those of us who remember the days when, as Lord Wolmer, he was actively engaged in fruit growing, to learn of his resignation due to ill health in June. Sir Albert Stern has now succeeded him as Chairman. Further, we have been pleased to learn that Lord Brabourne, Sir Edward Hardy, and Sir David Bowes-Lyon have accepted invitations to become Trustees; their wise counsel will be of great value in the years ahead.

Committees

Elsewhere in this report, details will be given of the land that has been acquired by the Trustees of the Development Fund. In the complicated negotiations that led to the satisfactory conclusion

of the purchase, we have particularly to thank one member of our Executive Committee, Mr. Stuart Dixon. Without his expert assistance, we might still be without this substantial advantage to the future working of the Station. We should also not forget Mr. B. S. Furneaux who, in conjunction with Mr. Goode of the staff, carried out a comprehensive survey of the soils on the new land.

All the Committees have met regularly, as in the past, and there has been no lack of work for their members. Professor Bennet-Clark deputized for the Chairman and Mr. P. Wheldon for the Chairman of the Finance Committee, during their absences abroad.

In January 1959 Professor F. G. Gregory of the Institute of Plant Physiology, Imperial College of Science, retired after twenty years' close connexion with the work of the Station and nine years as a co-opted member of the Executive Committee. Tribute to Professor Gregory's work in London has been made in many quarters ; for us, we would gratefully record that he ably carried on the tradition of collaboration between the Institute and ourselves initiated by Professor Blackman many years ago. As reported on page xx several of his team have now joined the staff of the Research Station.

The retirement of Professor Gregory and the untimely death a year ago of Professor Maskell, left two vacancies among the co-opted members of the Executive and, in October 1959, we were glad to learn that Professors W. O. James (Imperial College) and P. F. Wareing (University College of Wales) had accepted invitations to fill them.

A sub-committee has been formed to review the subscription rates for membership of the East Malling Research Station Association ; it consists of the members of the Standing Committee plus Mr. P. Wheldon and Mr. C. R. Favell, the elected representatives of the Association on the Governing Body.

The Trust Land

Without doubt in 1959 the Research Station has made the biggest step forward since the Bradbourne estate was acquired twenty years ago.

In March the Executive Committee met specially to consider the purchase of 140 acres of Ditton Court Farm adjacent to and to the North and North East of the existing farm. We have frequently lamented the growth of housing estates and industrial undertakings around us and this area is literally the last that is likely to become available on which fruit experiments can be carried out. It is therefore with some sense of pride that we report that the Trustees of the Development Fund, with the full backing of the Executive Committee, have bought this land and that, in consequence, a steady intake of new land fit for research purposes has been secured for the next quarter of a century.

It must be made quite clear that this land has been acquired, with the warm approval and admiration of the Agricultural Research Council, without any expenditure of public funds, and that it will be the property of the Trustees. The purchase is of profound importance to the future of the Station and of its research, especially in enabling the continued emphasis of the work to be on field experiments rather than on less immediately applicable investigations carried on within the four walls of a laboratory.

It may not always be realized that all the land on the existing 360-acre estate on which it is possible to grow fruit, nursery material or hops, has already borne one or more experiments during the past 48 years, so that there is now no ' open ' land left ; some of these experiments have been on fruit trees which have occupied the ground for 30-40 years. The staff have therefore had to face either curtailing the programme of field experimentation severely or the unacceptable alternative of using the land again before it has been properly ' rested '. The period for which land should be rested by growing uniform arable crops, long-term leys, etc., varies with the fruit crop that previously occupied the ground—after a long-term manurial trial, for example, many years may elapse before it can be used again. It has been agreed that for each new area on the Trust Land that is absorbed by the experimental farm, an equivalent area on the old land will be rested for a longer period than would otherwise have been possible. It will thus be possible to maintain the present acreage of experiments with the advantage that the new land will enable future experiments to be conducted more efficiently. According to the present programme, 25 acres will be absorbed in 1961/2 ; this to be repeated at five-year intervals thereafter.

It is a pleasure to acknowledge the substantial aid received from the Survey Branch of the Ministry of Agriculture. It is some years since the Branch placed the Station in its debt by carrying out a large-scale survey of its land ; this year a similar survey was carried out on the Trust Land, in preparation for its use for experimental purposes.

General

The events of the year have been to some extent overshadowed by the acquisition of the Trust Land referred to above. Nevertheless, there are many problems on a Station of this size for the solution

of which we are indebted to the members of the sub-committees of the Executive Committee and the staff standing committees. Thus, while the future needs for land are assured, day-by-day problems in the maintenance of buildings, farming the land to the best advantage, replacement of implements, issue to the fruit industry of information, new or improved plants, relations with other scientific institutes, staff visits in the United Kingdom and abroad are likely always to be with us. Some of these subjects are worthy of special paragraphs on their own account, others are briefly summarized here.

Buildings, Maintenance, Land, etc.

The maintenance staff are still engaged on a variety of tasks. The repairs and renewals at Bradbourne go steadily ahead, both in the house and the stables. The last of the four garages being built for the Church Fields houses has been completed. A loan has been made to enable a new boiler to be installed at the Grange, and the hot-water system for Fircroft has been overhauled. With the Trust Land the farm has acquired the tenancy of five cottages to help house our agricultural workers. The staff pavilion has been altered to allow of more changing room accommodation.

Neighbouring housing estates are largely responsible for the problems of trespass and damage now arising. While we always have to guard against the damage done by hares (a very present problem as we write) and other animal pests, the depredations of human trespassers are even more difficult to control and large sums and much effort have to be expended each year to protect our experiments from damage.

We have now sold 31 Buckland Lane, Maidstone, bought by the Association after the war to ease the shortage of accommodation for the research staff.

The Grange and the Canteen

Towards the end of 1958 it was clear that once again the Grange, though fulfilling its purpose, was not making ends meet. An all-round increase in rentals had therefore to be made in November. This must be regarded as inevitable in the light of the general increase in the cost of living.

Reorganization of the staff of the Canteen has sufficiently reduced overhead costs to enable it to pay its way even though the number of individuals using this facility has not changed markedly. The intervention of the Executive Committee was not required and it seems likely that the year will be completed in a better financial position than it began.

Dispatch of Fruitlets to Australia

An unusual task of a collaborative nature to which it is perhaps worth drawing attention here was the dispatch, at the request of the Australian C.S.I.R.O. of 100 lb of apple fruitlets, to enable research to be continued there throughout their winter months. The fruitlets were collected here under the supervision of Dr. Montgomery, and with the assistance of the Ditton Laboratory and the Veterinary Research Station at Weybridge, freeze-dried, packed and dispatched.

Finance

The Research and Experimental Farm Accounts

The administration of the finances of a large Institute is never easy. In this respect 1958/9 was no exception.

It is sometimes thought that the contribution of the State to our researches might be larger ; but, when all other commitments for which the taxpayer has to find the income are remembered, £245,000, the total grant from the Agricultural Research Council, seems no mean sum.

In fact the increase of some £20,000 over the previous year was entirely due to annual increments and the full effect of staff salary revisions, some of them overdue, made in 1958. Actually the sum expended on laboratory maintenance was somewhat less, while the contribution of the Council (£27,957) to the cost of running the experimental farm (£63,000) was only slightly more than in the previous year and still under the estimate. This was largely due to the constant vigilance of the Farm Supervisor and another good season in which the value of produce and crops reached nearly £35,000.

East Malling's main work lies in the field, a fact which is demonstrated clearly in the accounts, wherein it is shown that expenditure on the experimental farm (apart from labour) is nearly as much as that on the rest of the Station.

The East Malling Research Station Association

In former times, before the serious depreciation of the pound sterling, the income from the Association's Members enabled substantial sums to be accumulated and used for the benefit of the

Station. Now £5,000 has been donated to the Development Fund towards the purchase of the Trust Land. This land will be rented and farmed by the Association, 25 acres of it being released for research every 5 years.

The present income from subscriptions and donations is about £4,200, of which £1,400 is contributed to the maintenance of research ; another £1,200 is needed to cover the costs of the Association and of the direct benefits that Members receive. Among these are the Annual Report, invitations to attend four Members' gatherings a year, and accounts of those occasions that are sent out so that all members including those who cannot come may be informed.

It is easy to see that such items could absorb the whole income of the Association as it is at present, so that unless the income can be increased, the other activities that it now finances (none of which are eligible for Government grants) must be abruptly curtailed, while there would be no balance that could be added to the capital fund that has proved so valuable for emergencies in the past.

The amounts spent on some of these activities are shown in the account. They include such worthy causes as the Blackman Studentships, to which was contributed in 1959 six shillings of every two-guinea subscription, the farm pensioners fund (2s. 6d.) and that valuable fund that was used last year and will soon be used again to enable members of the research staff to obtain orchard experience overseas (2s. 6d.). In addition, another two shillings has sufficed to make capital contributions towards the sports and entertainments of the staff, and for evening classes in the neighbourhood for those of our juniors who desire to improve themselves.

So that none of these objectives may be handicapped, the Committee is now consulting the whole Association, as to the best means of restoring its income to its pre-war value ; the recommendations that result from this investigation will be placed before the Annual General Meeting in May 1960. There is every indication that a very large majority of the Members are willing to support the Committee's efforts, and it is particularly heartening to find many Life Members, who have supported the Station in the past, ready to renew their contributions now.

The East Malling Research Station Association
Income and Expenditure Account
1st October 1958 to 30th September 1959

Expenditure	£	s.	d.	Income	£	s.	d.
Research Contribution	1,381	0	0	Subscriptions and Donations	4,215	7	6
Evening Class Fees	75	4	6	Miscellaneous Receipts	1	12	6
Staff Amenities	120	0	0	Interest on Investments, Loans, etc.	226	16	5
Studentships	600	0	0	Sales of Annual Report Index	32	10	0
Farm Pensioners	250	0	0				
Orchard Experience Overseas	250	0	0				
Rent of Land and Cottages	525	12	7				
General Expenses	1,184	4	3				
Surplus	90	5	1				
	£4,476	6	5		£4,476	6	5

The East Malling Research Station Association Balance Sheet
at 30th September 1959

	£	s.	d.		£	s.	d.
Accumulated Members' Fund:				Freehold property at cost:			
Balance at 30.9.58	16,916	10	3	Fircroft and Grange	8,792	13	7
Add surplus for the year	90	5	1	Studentship Endowment Fund:			
	17,006	15	4	Investments at market value	11,635	10	0
Less loss on sale of 31 Buckland Lane and Investments	1,302	6	11	Cash at Bank	1,915	18	10
Donation towards purchase of land	5,000	0	0		13,551	8	10
	6,302	6	11	Loans	457	18	6
	10,704	8	5	Sundry Debtors	383	7	3
Studentship Endowment Fund	13,551	8	10	Deficit on rentals and farming	447	8	0
Farm Pensioners Fund	648	16	5	Cash at Bank	2,081	12	6
Sundry Creditors	809	15	0				
	£25,714	8	8		£25,714	8	8

Members' Days

Preceding the Amos Memorial Lecture on 13th November 1958, the opportunity was taken of telling growers what had been found out about the recently-arrived disease, fire-blight of pears. The rest of the programme dealt with new irrigation experiments on raspberries and black currants, and work on apple scab infection periods. The Station's meteorological plot was visited and the various instruments and records described.

Research on hop diseases was discussed on 10th December. Three new wilt-resistant varieties were described both from the point of view of the grower and that of the brewer. This was followed by talks on the occurrence of severe wilt in tolerant varieties, how the fungus invaded hop plants, and how it survived and spread in the soil. Recent work on the virus diseases, nettlehead and split leaf blotch, was also described.

The samples of Cox's Orange Pippin from growers in many parts of the country were on view to Members on 18th March, after five months' storage in a scrubbed gas store. In the morning the control of *Gloeosporium* rots was discussed, leaving the whole afternoon for the review of the storage results relating to breakdown, bitter pit, and general fruit condition.

On 12th May, following the Annual General Meeting, a wide choice of informal walks and talks on research in progress was provided.

Cherry-growing problems were reviewed on 8th July, with special emphasis on the control of bacterial canker and the elimination of virus diseases. The treatments proposed for a new soil management and manurial trial for cherries were discussed and methods of tree raising and shaping demonstrated.

Amos Memorial Lecture

The eleventh Amos Memorial Lecture was delivered at the Research Station on 13th November by Sir David Brunt, who was one of the first of the leading meteorologists to take an interest in the problems of fruit growers. The full text of his paper dealing with meteorological factors in plant growth was published in the 1958 report.

Staff

Looking through the staff list of a year ago, at first sight there seems little change to record. However, in a year that has seen the fortieth anniversary of the planting of the first apple rootstock trial in Great East Field, it is inevitable that some names that have adorned the list for many years no longer appear or have changed their position.

Bradbourne has been most affected due to the retirement of Mr. Akenhead and Mr. and Mrs. Phillips, and the resignation of Mr. Littlehales.

Mr. D. Akenhead built up the Bureau from scratch over a period of thirty years until he retired at the end of March 1959 ; indeed to many of the staff he *was* the Bureau. We all wish him every happiness in his retirement. Mr. and Mrs. Phillips had likewise become an institution at Bradbourne. Long before we came there they had served the late Sir John Twisden, taking over the duties of resident caretakers in 1939. They have now retired to their new home at Leybourne, where we hear Phillips is already making headway in his garden.

Mr. Littlehales came as assistant to Mr. Royle in January 1950, succeeding him as secretary two years later. He resigned at the end of 1958 to take up an appointment with the Cement and Concrete Association. He will be long remembered for the part he played in planning the extensions to the Empire Marketing Board and Manwaring Buildings.

Two major changes have taken place at the Laboratories during the year. With the retirement of Professor F. G. Gregory in January 1959 the Research Institute of Plant Physiology, Imperial College of Science, was dissolved. We are glad to report, however, that this has not entailed the loss to us of several of its members who have been working at East Malling for a long time and have now joined the staff.

On 1st October 1959, the former Plant Analysis Section was amalgamated with the Fruit Nutrition Section under the leadership of D. W. P. Greenham. This followed the resignation of A. C. Mason in June to take up an appointment with the Atomic Energy Authority at Capenhurst, Cheshire, and the retirement of H. J. Philcox at the end of September. Both were formerly members of the old Biochemistry Section under W. A. Roach, having been appointed in 1946 and 1948 respectively. We regret to report the passing of yet another former stalwart of that Section and an old friend of the Station—Miss M. E. Bunyard, whose death in May many of us mourned.

A. M. Massee, who was during the year created an honorary Fellow of the Royal Entomological Society, originally came to East Malling in 1920 and later formed and developed the Entomology

Section. At the end of the year he handed over the reins of the Section to G. H. L. Dicker, but we are glad that he is staying with us to pursue his studies of *Bryobia* mite.

During the year four of our Heads of Section have been abroad for extended periods—W. S. Rogers in Australia and New Zealand for 6 months, A. F. Posnette for 4 months and H. W. B. Barlow for a month, both in North America, and S. C. Pearce for 6 weeks in Ceylon. We would like to thank their deputies, Miss Beakbane, J. E. Crosse, D. H. Maggs, and P. Sprent, who carried on during their absences so efficiently.

R. V. Harris was installed as President of the Association of Applied Biologists in April.

It is with particular pleasure that we record the recognition by Her Majesty the Queen of H. M. Tydeman's long and painstaking work in fruit breeding by the award of the M.B.E. in the New Year's Honours.

Four members of the research staff and two assistants (scientific) of the Institute of Plant Physiology have now been absorbed on the permanent staff of the Station, while Mrs. C. C. Cole (*née* Macnamara) is now working at Ditton Laboratory.

As well as the changes due to the amalgamation noted above, M. Allen and one assistant (scientific) have now been transferred from the Plant Protective Chemistry Section to the Fruit Nutrition Section.

Despite the impression gained at a recent Christmas party that quite a lot of faces had been around long enough to become familiar, there are still a number of changes to record among the Assistant (Scientific) Staff. Those who have joined will be found in the staff list. A. B. Russell and R. C. Hardwick resigned from the Pomology Section in April and July respectively and Mrs. Newton (*née* Peters), Statistics, in December 1958. A. C. Morris and Miss Goodger of the former Plant Analysis Section left in autumn 1958 and J. Elliott, who had made himself known beyond the confines of the Fruit Nutrition Section as a cricketer and also a performer on the stage, entered a teachers training college at Portsmouth in September. Miss Dietz and Miss Bolton (Pathology) left towards the end of 1958 ; Miss Gobel (Entomology) started nursing in February, while Miss Moysey (Entomology) became a dark-room technician at St. Mary Abbots Hospital in July. Mrs. Barson (Plant Protective Chemistry) returned to California in November 1958 and Miss Mills and Mrs. Nevill also left the Plant Protective Chemistry Section in May and September respectively.

Finally, another familiar face is absent from the Workshops, K. W. S. Bunyard having resigned after ten years' service.

Mr. G. K. Argles was appointed Director of the Commonwealth Bureau in April. He is no stranger to many of us, having been Assistant Director since March 1950, after serving as a member of the Bureau scientific staff twelve years earlier. In July we were all pleased to hear of the promotion of Mr. G. E. Tidbury to Assistant Director.

On the Farm there are few changes to report, save for the much-regretted death of F. J. Page after 28 years' service.

On the administrative staff, R. L. Oxley was appointed in succession to Mr. Littlehales as Secretary at the beginning of the year and W. J. Clarke joined as Assistant Secretary in February. Miss M. B. Knighton-Hammond came as secretary to Mr. Oxley in August. There have also been rather numerous changes in the junior clerical staff.

Mr. and Mrs. J. H. Gardner settled in as caretakers of Bradbourne House at the end of May.

Last year we included a brief account of the history of the Library, anticipating the retirement of Mr. Akenhead. We would now add a word of gratitude to him. As his successor Mr. Argles is finding, the work of the Chairman of the Library Committee is no sinecure, despite the assistance of Mr. Ball and Miss Durling and we would here and now thank all three for the hard work they put in on our behalf.

The Library Committee is not the only one on which a large amount of unobtrusive work is put in by its officers. Exhausted by the complications of 1958, G. A. Booth has retired from the Canteen Committee in favour of R. C. Muir, who is now Chairman, and, we hope, finding an easier row to hoe.

Organized Visits

Three staff visits were organized in 1959, one to a sister research institute, the second to an experimental horticulture station, and the third to two adjacent farms nearer home.

On 2nd July, two busloads carrying a very large proportion of the scientific staff visited the recently-established Glasshouse Crops Research Institute at Littlehampton. The Director, Mr. F. W. Toovey, welcomed the party on arrival, outlining the work and organization of the Station, after which different departments were visited in turn in the glasshouses and laboratories. A feature of the visit was the opportunity arranged for free movement and interchange of views between scientists with similar interests. Coupled with the very friendly reception, all were impressed with the real progress made in the short time since the Station moved from Cheshunt to Littlehampton.

On 20th July, the experiment was made of arranging for a party to visit Luddington, Stratford-

on-Avon, travelling in their own cars and making their own arrangements for overnight accommodation. A larger party than was anticipated made the journey and were welcomed by an old friend, Mr. T. Laflin, who gave an account of the history and work of the Station. This was followed by a tour of field experiments with fruit, vegetables and flowers. Many naturally took a particular interest in the fruit plantations, some of them sponsored from East Malling, in which drought effects were at the time evident on the lighter soils.

In mid-August two farms with similar soils at Mereworth and West Peckham on the slopes of the Medway valley were visited. Barons Place, Mereworth, originally planted by the late Mr. Bernard Champion in the traditional style of many Kent farms, was shown by the present occupier, Mr. Hugh Lowe, who gave a clear account of the problems in the management of old-established orchards under modern conditions. For example, there were 50- to 60-year-old Bramley's Seedling trees planted only a few years later than those planted in 1894 by Mr. Fred Smith at Loddington which farm was visited in 1957.

Later the party moved on to Court Lodge, West Peckham. Here Mr. Bob Corfe led us through his orchards where healthy trees, some of them nearly 60 years old, were bearing impressively large crops.

The arrangements for both these visits were made with the valuable help of Mr. Owen English, who has had a particular interest in these farms for many years.

We should like to thank all who helped to make these visits so interesting and enjoyable.

Social and Athletic Activities

For the second year in succession Mr. B. F. Self was elected Social Secretary. He is particularly to be congratulated on the success of his efforts to inform newcomers to the staff of the various club activities ; changes among the junior staff are nowadays rather frequent, so that this duty of the Social Secretary is a very important one. It is refreshing to find none of the usual complaints about the weather in Mr. Self's report for the year.

It is a commentary on the changing habits of the staff (not perhaps confined to East Malling) that three car and motorcycle rallies were held, each with a large number of entries—no wonder the car and motorcycle parking problem at the Station becomes more acute each year.

The athletic clubs have again been able to report successful seasons. Indeed the Members will have to look to their laurels, for Cricket and Tennis Clubs both defeated them while, at hockey, in two matches, the honours were even. The Skittles Club has been well supported by the farm staff, to say nothing of some members of the research staff, and we would draw attention to the renewed life displayed by the Boat Club. Table tennis and netball are still popular, while evenings at the Maidstone Squash Club have been very well attended.

The better changing room accommodation in the pavilion is much appreciated and although we were unable to arrange a grand opening ceremony for the new shower baths at Bradbourne, an attempt was made to remedy the matter at the ensuing Christmas party.

All the now familiar social events, such as the Christmas pantomime, once again produced by the indefatigable Barbara Seymour, and the Children's party were arranged as usual. Judging by the speed with which Mrs. Tubbs' excellent tea vanished there must have been a lot of children there ; but we fear we have lost count of their numbers. In this connexion, we note a large increase in the number of children's entries for the Garden Club Show. Are there more of them or are they becoming more horticulturally minded?

While gramophone concerts and evening excursions to concerts and operas are still a feature of the Music Club's activities, the lack of a piano of sufficient merit to satisfy the more musical has been a handicap.

Finally we would acknowledge how much the Station owes to those who organize the many staff activities. The Association with its annual grants, tries to see that the various clubs are properly equipped, but it is on the enthusiastic support of the members of those clubs that their success depends and it is a pleasure to report that this shows no sign of diminishing.

Postgraduate Students

The second award of a Blackman Research Studentship was made in July. D. S. Skene, who came from Aberdeen, will study problems of skin finish in top fruits, especially the russeting and cracking of apples and other fruits, in the Pomology Section.

Seven members of staff and three others are now registered for higher degrees with London University. The two from abroad come from South Africa and India.

Two members of the Physiology Section, C. A. Priestley and D. J. Avery, have been awarded Ph.D. degrees by London University during the year ; also R. T. Burchill of the Pathology Section

was awarded a Ph.D. degree by the University of Bristol for work on apple mildew carried out before joining the staff here.

All other students who have studied with us for periods of a few weeks to nine months have either come from abroad or have spent time here before taking up posts in the Commonwealth. Countries with which among many others we now have such contacts include East and West Africa, Malaya, Ceylon, Portugal, Israel, and the Lebanon. D. A. Burdekin completed his nine months pathology course in June, B. R. Buttery, K. F. Daouk and M. Shafrir all worked in the Pomology Section, D. K. Acquaye and D. A. Lawes in Fruit Nutrition, J. R. Cranham in Entomology, A. M. S. Fernandes in Plant Protective Chemistry and G. A. Watson in Statistics.

We should not conclude this section without mentioning Miss Lotti Huber of Wädenswil, who is here for a year in exchange with Miss Pauline Topham and Miss Jean Smith, each of whom are thus able to spend six months in Switzerland. Also J. Kyriakides from Salonica spent a month assisting in the Pomology Section during the summer.

As far as our accommodation allows, we always welcome such visitors and look forward to more of these valuable contacts in future years.

Temporary Recorders

The number of applications from undergraduates at British Universities and Colleges was less than in recent years and we are tempted to wonder what has happened to the students from the Imperial College, Wye and from Oxford and Cambridge, whence we have had many applications in the past.

Altogether sixteen came to help us and gain experience of research in the field for themselves. All spoke appreciatively and enthusiastically of their month at East Malling, so that we trust that the economic factors that affect so many undergraduates of today will not seriously curtail this most valuable scheme for encouraging the research workers of tomorrow.

Plantation Assistants

Again the team of 10 plantation assistants was predominantly male, indeed applications from girls are rare. Some of those who come are not very experienced when they start, but most of them work enthusiastically and well and are a great help to our research staff in the conduct of field trials.

After fourteen years it is becoming a commonplace to meet esteemed workers in the horticultural world, who have served a term in the plantations at East Malling.

We congratulate this year's winner of the Worshipful Company of Fruiterers prize—Robin M. Wates. He is now working at Luddington Experimental Horticulture Station.

Staff Discussions

Climate, the spray programme for apples, fruit bud development, and plant variation were the four subjects chosen for general discussion by the whole staff. We would thank all those who introduced these subjects, for it is not easy for the specialist to put over his ideas simply to colleagues who are perhaps hearing of them for the first time.

Perhaps the atmosphere of the discussions at Bradbourne is rather over-awing and there may be a tendency to leave the talking to the more senior or uninhibited members of staff. Anyhow, at the more intimate exchanges of ideas between two or three sections the specialists seem to have let themselves go, for it is reported that the discussions on these occasions were particularly lively. Powdery mildews, organisms damaging ripe strawberries, soil uniformity, and means of expressing analytical data were the subjects that provoked much argument.

One form of ' Discussion ' that is not often heard of is the Pomology meeting every Saturday morning. To listen to the arguments that take place every week is an education in itself.

East Malling Abroad

If we have welcomed many research workers from abroad during the year, our own staff have by no means all stayed at home.

W. S. Rogers spent six months in Australasia, visiting Hawaii, California and Trinidad on his way home. A. F. Posnette, R. S. Pitcher, H. W. B. Barlow and Barbara Mosse have been for varying periods in the United States and Canada. All four attended the International Botanical Congress in Montreal, the last three contributing papers and demonstrations in their several spheres. H. W. B. Barlow also contributed to a conference on Growth Regulators in New York.

R. L. Knight has been to Israel and Germany, S. C. Pearce to the Tea Research Institute in Ceylon, G. H. Freeman and G. C. Head to Holland, and D. W. P. Greenham to Belgium.

R. J. Garner returned from six months' secondment to the Rubber Research Institute in Malaya in January and Miss Elsie Collyer left for a year in New Zealand in August.

These most valuable and refreshing journeys to different parts of the world have been made possible by financial assistance from many sources. Of these we must mention first the Agricultural Research Council and our own Association. But we are also indebted to the Rockefeller Foundation, the Governments of Canada and New Zealand, the organizing committees of the New York Conference and the Montreal Congress, the British Council, the Weizmann Institute of Israel, the Max-Planck Institute of Cologne, the Rubber Research Institute of Malaya, and the Tea Research Institute of Ceylon. To all these authorities we would say 'thank you' for making these visits possible. They are of the utmost value to the investigations at East Malling, to the staff concerned, and to the wider cause of world research in general.

Collaboration

The dissolution of the Institute of Plant Physiology terminates a period of collaboration that has lasted for nearly forty years, first through the interest of Professor V. H. Blackman and later that of Professor F. G. Gregory. Although the Institute no longer exists, a new period of collaborative research may be said to have started in the integration of several former members of its staff with our own.

This year the list of visits to other research institutes in the United Kingdom by members of staff is so long that we have been unable to include it here. Looking through the reports, however, we are struck by the numbers of such visits that have as their primary object the discussion of a collaborative project. Perhaps, we may single out Rothamsted for special mention, since they found room there to accommodate two members of our staff for longer periods—Miss Delap who spent the summer in the Botany Department and R. T. Burchill, three weeks studying the art of spore-trapping with Dr. Hirst. A glance at the visitors' book shows that such visits are by no means one-sided, since many of the staff of other institutes have come to see us here.

Each year we hear of more and more instances of co-operative experiments with the National Agricultural Advisory Service, both at Experimental Horticulture Stations and in the field. So long as such a close association is maintained the industry will be well served.

The list of experiments on fruit-growers' farms is likewise so long that we cannot detail most of them ; indeed many have already been in progress for several years. The planting of a new apple rootstock trial on a farm at Histon owned by Messrs. Chivers Ltd. is perhaps worthy of special mention, as is a new experiment on the spread of nettlehead in the hop gardens of Mr. J. G. Calcutt at Cranbrook.

We apologize for this inadequate account of a very important side of the Station's activities. As the facilities for research grow, and those who grow fruit for their living become more and more interested in its progress and results, so do opportunities for collaboration increase.

Scientific Societies and Conferences

The recent growth of meetings of small groups of specialists is helping to supplement the work of the large international congresses where time is often too short for adequate discussion. In 1956, the same year in which the Acarologists' Symposium was held at Wageningen, we welcomed European workers interested in virus research. In 1959 the acarologists likewise spent three days at East Malling not only to discuss details of nomenclature, life history, predators, chemical control and resistant strains, but with time to see and hear about aspects of our own research on mites affecting fruits.

Many members of staff have attended and spoken at the regular meetings of scientific societies, especially those of the Association of Applied Biologists (A.A.B.), the Society of Experimental Biology (S.E.B.), the British Mycological Society (B.M.S.), and the Royal Entomological Society (R.E.S.).

At the joint meeting of the A.A.B. with the Horticultural Education Association, W. S. Rogers gave a paper with G. A. Booth on root growth, and H. W. B. Barlow one on root/shoot relationships. E. S. J. Hatcher spoke on propagation from stem cuttings at an A.A.B. Symposium, and R. J. Garner opened the discussion. H. W. B. Barlow with C. R. Hancock and H. J. Lacey demonstrated to the S.E.B. the klinostat they had developed for growth substance studies. R. T. Burchill described his work on apple mildew to the B.M.S. in London and demonstrated the life cycle of the disease when the society held its field day at Long Ashton. A. F. Posnette gave a paper to the Linnean Society on leaf-hopper transmitted viruses, and Miss Beakbane spoke to the newly-formed Plant Anatomy Group of this society on causes of variation in the anatomy of clonal fruit trees.

Generally the research staff must travel to present their results to learned societies but there were two exceptions this year when the societies came to East Malling instead. In April, the Plant Anatomy Group of the Linnean Society made history by meeting at the Station, when members of staff from different sections described work on rootstock selection, growth analysis, fruit abscission

and development, mycorrhiza, and diseases, in all of which anatomical studies were involved. The Institute of Biology (London Branch) having cancelled a lecture by R. L. Knight in January owing to thick fog, came to East Malling in July to hear him and Miss Keep describe their work on soft fruit breeding.

S. C. Pearce with D. A. Holland gave a paper on applications of multivariate analysis in fruit tree research to a symposium of the Biometric Society. G. H. Freeman lectured to the staff at Wageningen on the analysis and interpretation of experimental results. R. I. C. Holloway contributed a paper to the Weed Control Conference at Brighton and E. S. J. Hatcher spoke on mist propagation at a conference at Wye College.

The Station was represented at the A.R.C. Conference on apple scab by Drs. Crosse, Moore and Burchill, on virus diseases of clover by Miss Ellenberger, and on insecticides, fungicides, and weedkillers by M. Allen.

Information Services

Correspondence, lectures, demonstrations and exhibits

The complaint that the results of research are not reaching the commercial grower is still to be heard despite the efforts of the Advisory Services and the enthusiasm with which their members seize on any opportunity we offer to keep themselves up to date, such as the annual two-day visit, Members' Day rehearsals and refresher courses. Sometimes we wonder whether growers take advantage of all the opportunities offered them in this respect.

However, the Station itself is constantly kept in close touch with growers' problems, particularly of course, through Members of the Association. During the year well over 1,000 letters and innumerable 'phone calls were received, and in dealing with the problems raised some thirty-two visits to individual holdings were made, apart from many other visits of a purely research nature. Twenty-seven lectures were given by members of staff, mainly to N.F.U. branch meetings and discussion groups, on pruning, propagation, soil management, diseases, and pests as well as on more general subjects. Although twelve of these were given in Kent and neighbouring counties, the rest were well spread over the main fruit-growing areas in the eastern counties, the west midlands and the south west. In addition members of staff gave demonstrations of pruning and grafting in several centres, and took part in four brains' trusts. They assisted with judging at the Kent Cherry and Soft Fruit Show, the Marden and East Kent Shows, and at amateur shows at the R.H.S., London, at Platt, and at Tunbridge Wells. Staff members also took part in judging the orchard spray competitions at Kirdford and at Paddock Wood.

The Maidstone branch of the N.F.U. again asked to be informed of the occurrences of Mills' Periods for scab infection at the Research Station. As a result of experience during the previous season, the warnings were given weekly, because the more frequent notices had been confusing to growers. An attempt was made also to give less detail and more direct guidance when a spray was advisable.

Exhibits of research in progress were staged at five important shows. At Chelsea our exhibit demonstrated work on the development of fruit buds in relation to regularity of flowering. At Maidstone the subject was the effect of soil management and irrigation on growth and cropping. Several aspects of rootstock research were presented at the Sesquicentenary Show of the Royal Caledonian Horticultural Society, and new rootstocks for apples were demonstrated at Marden. An exhibit on walnut research won a Lindley Silver Medal for the Research Station at the R.H.S. Autumn Show in London.

On the occasion of the Masters Memorial Lecture given by the Director in London, we illustrated his subject ' The Living Tree ' with exhibits of some of the work he described.

Visitors

As the journey from London is quick and easy, most of the visitors to this country who are interested in horticultural research or fruit growing spend at least a day at East Malling. It is not surprising, therefore, that about a quarter of the 2,100 visitors during the year came from overseas.

From Australia, we received Sir John McDonald, of Shepperton, former Premier of Victoria, Mr. F. Melville, Senior Fruit Adviser, W. Australia, and Dr. R. N. Robertson of the C.S.I.R.O. Executive and the Botany Department, University of Sydney ; from Canada, Dr. J. Marshall, Senior Entomologist, Summerland, B.C. ; from Ceylon, Dr. D. L. Gunn, Director designate of the Tea Research Institute ; from Denmark, Dr. S. Dalbro, Professor of Horticulture, Royal Veterinary and Agricultural College, Copenhagen ; from Ghana, Mr. Quist Therson, Permanent Secretary to the Ministry of Food and Agriculture, accompanied by Mr. J. Lamb, Director of the West Africa Cocoa

Research Institute ; from Italy, Dr. P. Columna, Head of the Phytopathology Service, Rome ; from Japan, Dr. M. Fukuya, Director of the National Institute of Agricultural Science, Tokyo ; fron Jordan, Dr. S. Nashef, Director of Research, Department of Agriculture ; from New Zealand, Dr. E. E. Chamberlain, Director of the Plant Diseases Division, Auckland, and our old friend Dr. L. W. Tiller, Assistant Secretary D.S.I.R., Wellington ; from South Africa, Dr. R. Marloth, Director of the Nelspruit Horticultural Research Station, Transvaal ; and from the West Indies, Mr. W. G. C. Forsyth, Director of the Colonial Microbiological Research Institute, Trinidad. Several of the delegates attending the Commonwealth Fruit Conference visited us, including Mr. N. April (Canada), Mr. J. Fernhout (S. Africa), and Mr. E. J. Greenstein (S. Africa). Mr. W. J. Kinghorn and Mr. J. Eaton visited us before taking up their posts as Agricultural Advisers to the High Commissioners of Australia and New Zealand respectively.

More than half our visitors come in parties and most of these consist of fruit growers and students from this country, Holland, France and Germany. It is, however, worth making special mention of the visits of the Royal Institute of Chemistry (London Section), the Institute of Biology (London Branch), the Plant Anatomy Group of the Linnean Society, and the South Eastern Regional Staff Council of the N.A.A.S. If the attendance on Members' Days and rehearsals is added to the figure for visitors given above the total is just over 3,000.

Distribution of Experimental Material

Although the printing strike delayed the issue of the 1959 Distribution List, this does not seem to have interfered seriously with the allocation of surplus plant material to Members. The year is noteworthy for the first issue of a re-selected clone of the old rootstock M.VII, free from rubbery wood, mosaic and chat fruit viruses. The produce of this clone will from now on replace that of the former untested stoolbeds which will be scrapped. It is hoped to follow it before long with similar re-selected clones of M.II and M.IX. In addition we have also been able to offer the new semi-dwarfing rootstock M.26 (a cross between M.XVI and M.IX), which was described in the Annual Report for 1957 (p. 48), but the issue of which was postponed last year. Both these rootstocks have been eagerly taken up by Members.

Among the Mother trees of virus-tested scion varieties we were able to offer for the first time nine varieties of plum, all except one on Myrobalan B, high-worked where the variety is susceptible to bacterial canker. Two virus-tested varieties from the John Innes Horticultural Institute, a re-selection of the apple Merton Worcester and the new pear Merton Pride, and three further cherry varieties were also added to the list of more than fifty varieties that are now available under the Mother Tree Scheme. To work all these varieties annually is beyond us ; but each year a list of varieties that can be grafted on request is given so that Members who wish to acquire varieties offered in former years, or those that are only occasionally wanted, can order them specially ; a supply of virus-tested rootstocks is planted each year against such eventualities.

As nurserymen and growers gain experience of them and as the various trials mature, the Malling-Merton rootstocks seem to be finding their level in the trade, though it is still difficult to forecast a year ahead what the needs for individual stocks will be.

Other items in the Distribution List were much as usual. At present there is a heavy demand for Quince A rootstocks, and for the recently-issued St. Julien A, while we can never satisfy all orders for the old Brompton plum ; there are also signs of a revived interest in rootstocks for cherries. But worked trees surplus to experimental needs are difficult to dispose of, probably because there are seldom enough of them to interest commercial growers, while amateurs are more interested in the sets of high quality varieties raised specially for garden use.

In this part of the report we have concentrated on the results of the season 1958-9, as evidenced by the plants we were able to offer in the autumn. Full details of the past season as it affected the nurseries will be found in the Farm Report. While we may look back to the summer of 1958 as producing a record number of first-grade rootstocks, we were by no means dissatisfied with the results of the much drier summer of the past year, which seems seriously to have reduced only the production of one-year bedded rootstocks and the rooting of cuttings of some varieties.

Station's Publications

A complete list of publications is given in Part II of the Research Report. There were 55 scientific papers and 17 practical articles for growers.

Journal of Horticultural Science

Volume 34, which again contained 29 papers, but used fewer pages than its predecessor, showed a tendency towards an increase in contributions from other Institutes in the United Kingdom and

abroad but a decrease in those from Long Ashton and East Malling. Since the scope of the Journal was widened and the word ' Pomology ' was dropped from the title twelve years ago, such a tendency was inevitable ; nevertheless, it would be a sad day should the work of the two sponsor Stations become too specialized to be published in the Journal.

If we may anticipate, it is a pleasure to report that Professor H. G. H. Kearns, who has for some time been doing the work, has now agreed to assume the title of Editor jointly with Mr. Hoblyn.

Library

On the 31st of March, 1959, Mr. D. Akenhead retired as Director of the Commonwealth Bureau of Horticulture and Plantation Crops. In the early days he acted as librarian and from 1947 was Chairman of the Library Committee. On his retirement he was succeeded as Chairman by Mr. G. K. Argles, the new Director of the Bureau.

The year has not witnessed any spectacular developments, but there has been a steady increase in the intake of publications and also in the use being made of them. This latter aspect is perhaps most clearly reflected in the rise in the number of periodicals on automatic circulation to different sections of the Research Station ; the total, in terms of periodical parts, has risen by 134 in the past three years and now stands at 976. A rather less satisfactory feature has been the rapid rate at which the few remaining empty shelves have been filling up. Already there is considerable congestion in some parts of the library, which is being met by an accelerated programme of binding.

RESEARCH REPORT

RESEARCH REPORT

Part I

THE EXPERIMENTAL FARM

In spite of the unprecedented drought, 1959 was on the whole a satisfactory year for both top and soft fruit production at East Malling. The mild, open winter was followed by a spring free from damaging frost and from bird damage. The wet March and April insured that there was ample moisture in the soil when the drought began so that its effects were not as severe as if it had followed a dry spring. The long spell of dry weather from May onwards made all cultural and harvesting operations relatively cheap and easy. The fine weather and high temperatures favoured most varieties both of top and soft fruits, despite the drought, and excellent crops were obtained. Only in isolated places where the soil is very light or gravelly were established fruit trees seriously affected by lack of water, which resulted in stunted growth and very small fruit. As might be expected, the growth of cuttings and of ' bedded ' rootstocks was also adversely affected by the drought, though the stool-bed production was very good.

The season was 10 days to a fortnight early throughout ; Early Rivers cherries were in full bloom on 19th April, the first strawberries were marketed on 9th June, and apple picking was all finished by 10th October, almost a month earlier than usual.

Experimental orchards

Top fruits

Apples.—A total of 256 tons of apples of all varieties was harvested in 1959, 61 tons less than the very heavy crop of the previous year. This was partly due to the grubbing of 2 acres of old Worcester Pearmain and partly because some biennial varieties were in an ' off ' year. However, the crop of Cox's Orange Pippin was only 4 tons less than in 1958 and, except for a few trees on Larkfield Plantation, fruit size was excellent. In fact on some trees with light crops the fruit was well above the ideal size. Trees in the pruning trial on Churchfields West, which have done very well for the past two years, did not come up to expectations, but the large 30-year-old Cox's Orange Pippins on M.XII in the manurial trial on Churchfields East, which cropped poorly in 1958, yield d an average of 440 lb per tree, one of the best crops for some years. Worcester Pearmain, our other main dessert variety, also cropped well, though unlike Cox, which seemed to thrive in the high summer temperature, fruit size was rather smaller than usual particularly where no thinning had been done. Where the fruit was thinned on the rootstock trial on Great East, fruit size was good and the yield excellent. These trees, now 39 years old, averaged 220 lb of picked fruit per tree which, on a 15 × 30 ft plant is equal to 522 bushels per acre. Whilst this spacing is obviously too close for the lighter pruned trees on the stronger stocks, it is still more than adequate for the hard spur-pruned trees on the more dwarfing stocks which contributed their full quota to this excellent result. As has been mentioned several of our other varieties were in an ' off ' year, but Laxton's Fortune on Churchfields averaged 80 lb per tree, and the crop of Jonathan was satisfactory ; this variety withstood the drought remrakably well. On the gravelly soil on Larkfield Plantation, Jonathan trees averaged 73 lb of marketable fruit per tree, whereas that from trees of Cox and Laxton's Superb on similar soil was useless.

Both our main varieties of cooking apples cropped heavily. Bramley's Seedling in the rootstock trial on Great East yielded 620 lb per tree and those on the manurial trial adjacent almost 750 lb, which at 30 ft square is equal to just over 16 tons per acre. This is particularly remarkable, as some of these trees have never received any fertilizer except a little potash since they were planted.

Pears.—After the exceptionally good ' pear year ' in 1958, the crop in 1959 was only 16½ tons, compared with 26 tons in the previous year. Conference cropped satisfactorily in all plots, though the fruit was somewhat small ; Williams' on the other hand cropped poorly, most trees carrying

only a few large fruits. The young trees planted on Deadman and Merryweather in 1956 and 1957, respectively, grew well in spite of the drought, and those on Merryweather carried a few fruits on some trees.

Cherries.—Although the weather at blossom time was fairly good, cherry crops generally, and early varieties in particular, were poor. The total crop from 6½ acres of fruiting trees of all varieties was only 5½ tons. Early Rivers, usually a most reliable cropper, only yielded an average of approximately 12 lb per tree from mature trees, and the crop of Bigarreau de Schrecken was negligible. Later varieties were somewhat better and similar trees of Turkey Heart averaged approximately 60 lb per tree. The only variety to crop well was Merton Bigarreau, 6-year-old trees on the younger plot adjacent yielding 23 lb of fruit per tree.

Plums.—In contrast to cherries, plums of most varieties cropped heavily and the total crop in 1959 was 38 tons compared with 26 tons in 1958. The crop of Victoria was slightly less but Ontario, Marjorie's Seedling, and Warwickshire Drooper more than doubled the yields of the previous year. Furthermore, younger plum plantations are now beginning to bear useful crops. In the trial of semi-dwarfing plum rootstocks on Egham Field, trees of Rivers' Early, planted in 1953, yielded 11 lb per tree and similar trees of Cambridge Gage yielded 14 lb. It was not necessary to thin the fruits on trees of Victoria in most experiments as the set was only moderate and, though both size and quality were affected by drought, the fruit was saleable. Warwickshire Drooper fruits on the other hand hung in clusters and were very small and hard to sell. There was little splitting or rotting on any of the varieties in the dessert variety collection, and the excellent quality of this fruit partly made up for the low price received for the heavier cropping varieties. The young trees in two trials on Egham Field, and also those interplanted amongst the cherries on Newgates Field, made excellent growth in spite of the drought.

Soft fruits

Although the acreage was again slightly reduced the total crop of strawberries remained at approximately 3 tons. Most varieties bore very heavy crops and there was little trouble with *Botrytis* or with seed-eating beetle. It was not possible to irrigate strawberries and many varieties wilted badly, particularly Cambridge Vigour, but Cambridge Favourite stood up fairly well. The most notable feature of the 1959 soft fruit season at East Malling was the excellent crop both of raspberries and black currants. Norfolk Giant and Exploit raspberries in Newgates Field, planted in 1955, did exceptionally well, the Exploit cropping at the rate of 5½ tons per acre and the Norfolk Giant at 4 tons per acre, this in spite of the fact that many of the latest fruits withered in the heat and failed to mature. Cane growth was again good and fully sufficient to carry another heavy crop in 1960, if conditions are favourable. Of the black currants planted in 1956/7, Wellington XXX cropped at the rate of 4·3 tons, Mendip Cross at 3·7 tons and Westwick Choice at 3·3 tons per acre. Growth of new fruiting wood was not altogether satisfactory except in Mendip Cross, and it is doubtful if this year's yields can be repeated in 1960 even under the best conditions.

Fruit marketing

A brief hailstorm in May damaged the fruitlets of many varieties of apples but, apart from this, fruit quality in 1959 was good. There was much less cracking and russeting than for the past year or two, and colour was excellent. The whole of the Worcester Pearmain crop was again marketed at picking time, and our two 2,000-bushel stores were therefore available for cooking apples. One was filled with Lane's Prince Albert and is being held at a temperature of 37° F with an atmosphere of 7% CO_2, and the other with Bramley's Seedling which are being kept at 38° F with 8% CO_2. The former will be marketed early in 1960 as soon as most of the ' barn stored ' fruit is off the market, and the latter in March when most of the cold-stored fruit is gone. Of the smaller stores, one has been filled with Barnack Beauty and Laxton's Superb, and the other with Cox's Orange Pippin.

As in the past, cherries and dessert plums were graded and marketed in 12 lb chip baskets, and culinary plums and raspberries sold for processing. The black currants were mostly marketed in ½-lb punnets, using the second-hand trays mentioned last year as ' punnet carriers '. This was costly in labour and packing materials but the good price received amply justified the extra trouble taken.

Fresh planting and grubbing

The expansion of our pear acreage and increased provision for the needs of the Pathology Section were the chief features of the 1959/60 planting programme. A trial of quince rootstocks, with Conference and Beurré Hardy as scion varieties, was planted on Merryweather (M3). Where the rootstocks are expected to be more vigorous, the trees are planted at 15 ft square, but at 12 ft square where the rootstock effect is expected to make smaller trees. On Egham (E29) ½ acre was planted

with Lord Lambourne on M.26 at 10 × 7 ft to be grown intensively as part of the virus-testing programme, and 1 acre with Cox's Orange Pippin and Worcester Pearmain at 17 × 15 ft for fundamental work on fungus diseases. Also on Egham (E35) a further ½ acre of Victoria, Denniston's Superb, and Oullins Golden Gage, all high worked on St. Julien A rootstocks, were planted to complete the plantation for future experimental use mentioned in last year's report. On Great East (G16) a further ½ acre of closely planted cherries and plums are being grown for work on bacteriosis, and on Churchfields West (C14) 1 acre has been planted with Cox's Orange Pippin to assess the effects of different lengths of intermediate, grafted between the rootstock and the scion variety. The only other plantings were two small areas of rootstocks on Egham Field (E29 and E30) for intensive work by the Physiology and Fruit Nutrition sections.

Two of the older rootstock trials on Egham have now been concluded, having completed their experimental usefulness, while their retention for the sake of the fruit they produce cannot be justified. These were the half standard Lord Derby (E30) and half the bush Cox's Orange Pippin (E32), the remainder being retained for other experimental purposes. The trees in both these trials were 38 years old. Also on Egham, part of an extended nursery trial of cherries (E28) and a stoolbed maintained for physiology studies (E21) have been cleared.

On Kiln Field the last three rows of old bush Cox's Orange Pippin and Worcester Pearmain on K3 have also been grubbed.

The attempt to maintain a small plantation of Sunset and Laxton's Fortune on M.IX in the very light soil on Larkfield for intensive studies requiring small trees has proved a failure, so the 12-year-old trees are being cleared. On Newgates, a further step has been made towards the clearance of a large field (N3) so that it can be restored to uniformity and fertility for future use.

Routine spray programme

Plum plantations, young trees, and the nurseries were again sprayed with 5% tar oil during December, as were all black currant plantations. Apples in Churchfields West were sprayed with a DNC wash containing 2·4% DNC in March. The main object of this was to help control the severe outbreak of mildew in this plantation in 1958. The pre-blossom apple scab programme consisted of two lime-sulphur applications and one of a mixture of ¾ lb karathane and 2 lb captan on Cox's Orange Pippin, and three lime-sulphur applications on other varieties. After blossoming, all varieties received six sprays of the same captan/karathane mixture except Lane's Prince Albert, which received karathane only, and Bramley's Seedling which had lime-sulphur throughout. Scab control was good and mildew much reduced as compared with 1958. The addition of 8 oz of metasystox to the green-cluster spray effectively controlled aphids, and 12 oz of metasystox in the petal-fall spray controlled sawfly and red spider until late in the season. Towards the end of July red spider appeared to be building up again and 1 pint of malathion was applied on 11th-12th August ; this prevented the infestation from becoming serious.

Two applications of lead arsenate were made against codling moth, one at the end of June and one in mid-July, but were not effective and damage from codling attacks was the worst for some years. It was hoped that the malathion applied in August would check the second generation larvae, but this was not so.

Pears were sprayed twice before blossoming with lime-sulphur, once at 2½% and once at 1½%, and BHC wettable powder was added to the first spray for the control of aphid. The petal-fall spray consisted of a mixture of 2 lb captan and 2 lb lead arsenate, and one further spray of captan was made at the fruitlet stage.

Having been winter-washed, plums received no pre-blossom sprays. Three weeks after petal-fall young plum trees were sprayed with a mixture of 12 oz of metasystox and 1 pint of a preparation containing 15% copper oxychloride, against red spider and bacteriosis. This treatment was effective against red spider but not bacteriosis, to which there does not yet seem to be a complete answer. Young cherries were sprayed five times with Bordeaux mixture, at white bud, in early May, mid-August, mid-September and mid-October, 6 pints of cotton seed oil being added to the early May and mid-September applications. This treatment, which has been carried out for the last three seasons, seems promising, for although there have been bacterial infections on young trees no trees have so far been lost. Fruiting cherries were sprayed three times, at white bud in mid-September and mid-October. DDT was added to the white bud spray for the control of aphids and cherry fruit moth.

Raspberries were sprayed only three times, once with 2½% lime-sulphur and DDT at bud-burst against cane spot and aphid, and twice with liquid derris against raspberry beetle. Beetle control was not complete, possibly because of bad timing of the spray.

Black currants, which were all sold for the fresh fruit market, were sprayed when the first blooms were open with endrin at 1½ pints per 100 gallons of dilute spray against big bud mite, and again directly after picking with Bordeaux mixture 4 : 6 : 100 plus 6 pints cotton seed oil against rust.

At the end of June a few of the bushes on the irrigation and nitrogen trial on Egham Field were attacked by capsid, but this was quickly dealt with by a DDT spray before damage became serious.

Arable crops

The area under arable crops remained unchanged at 109 acres. The weather was exceptionally favourable for arable crops, all of which, apart from main crop potatoes, did well in 1959 and in fact contributed nearly 25% to the total farm revenue. Now that a suitable rotation has been evolved, it is surprising how well these arable crops fit in with the fruit farm work to produce a very useful income for very little extra expenditure on labour and machinery. Although the modern trend is all towards the simplification of farming systems, the combination of some arable acreage and nursery work does provide a useful insurance against the dangers of over specialization in a product so dependent on the weather, and which is not within the scope of the annual price review.

Potatoes.—Eight acres of Craig's Royal, 7 of Majestic and 1 acre of Stormont 480 were grown in 1959. Five acres of Craig's Royal were marketed in August and yielded 8 tons per acre. The remainder, from which seed was wanted, were lifted in October, but because of lack of rain there was no increase in crop. Majestics were also lifted in the autumn but yielded only 7½ tons per acre and the Stormont 480 were even worse, only 5 tons per acre. However, it will be interesting to see how this variety behaves in a wetter season. As in the past, sodium arsenite was used to burn off the haulm before lifting, but this year only a small acreage was treated as most of the haulm had already withered. It was very noticeable that where sodium arsenite had been used there was much less slug and insect damage to the tubers. It would appear, therefore, that if an alternative to sodium arsenite is found, which is less toxic to human beings, it should still be toxic to pests.

Peas.—The same four varieties were grown for canning and quick freezing as in previous years and the results were even more satisfactory. The crop was again good but the growth of bine much less, so that there was a considerable saving in haulage costs. A residual herbicide was again used for weed control and, although it appeared to have done some damage early in the season, yields do not appear to have suffered, the 20 acres grown yielding 41 cwt per acre.

Cereals.—Thirteen acres of Cappelle wheat and 24 acres of Svenno were grown in 1959 and yields were the best for some years. One 5-acre plot of Cappelle yielded over 14 tons of grain. The Svenno did not do quite so well but the average of 30 cwt per acre was very satisfactory for spring wheat. Harvesting was easy and none of the grain needed drying, the only problem being to find storage room.

The 4½ acres of Cocksfoot grown for seed did not crop quite so heavily as in 1958, but seed was of excellent quality and received 8th prize in its class at the Royal Winter Fair at Toronto. Fifteen acres of clover and ryegrass were grown, of which 8 acres were made into silage and the remainder into hay. The first cut of hay was good but there was little or no aftermath because of the dry summer.

Forty-six dehorned Hereford steers were wintered in 1959 as it was found difficult to obtain dehorned Devons. The Herefords were very quiet and did well, but unfortunately did not meet a very good trade when sent to market.

Experimental nurseries

1959 was again a busy year in the experimental nurseries. Although the numbers of rootstocks lined out for budding have not increased greatly, the plums and cherries now produced are all high worked and consequently have to stay in the nursery one year longer; furthermore those that are staddle-worked require 3–4 grafts instead of a single bud, as with low-worked trees. The trees thus produced are, of course, much more reliable but considerable extra time and trouble is involved. The same is true to some extent with the stoolbed work where the production of virus-tested clones of the more popular rootstocks involves meticulous care and considerable extra supervision. Every tree produced is now a pedigree tree of which the virus status of the rootstock and scion are carefully recorded.

The production of virus-tested Mother trees for distribution to Members is now quite a formidable task. In the 1959 list, worked trees of 26 varieties (7 apples, 4 pears, 6 cherries, and 9 plums) were offered, while a further 28 varieties were listed as available for working on request.

The year was notable for the first offer to Members of a reselected clone of M.VII rootstock free of rubbery wood, mosaic and chat fruit viruses, and for the first issue of the new semi-dwarfing apple rootstock M.26.

The dry summer made weed control easy and there was little trouble with pests and diseases. Cuttings, however, did not appreciate the drought and the 'take' of several varieties was poor; bedded stocks, although mostly rooting, made little new growth and the proportion fit to line out for budding was below average. Rootstocks of all varieties lined out for budding grew well,

but some of the maiden trees on the poorer strips in Ditton Fields (mentioned in last year's report) grew very unevenly and results were somewhat disappointing.

The dry weather continued sufficiently into the autumn to enable most of the stool and layer beds to be harvested well before Christmas, and the crop was again a good one. The number of stocks fit to line out for budding was about 10% less than in 1958, not because of poor rooting, but because growth was somewhat restricted. Taking the wet year 1958 and the dry year 1959 together, stool-beds of MM.104 and MM.111 have yielded an average of well over 50,000 good grade stocks per acre.

Experimental glasshouses

The prolonged spell of sunny weather during the summer gave an excellent opportunity to test the effectiveness of the various systems of cooling glasshouses that are in use, and results confirmed previous findings. In particular, a dutch light house with heat-absorbing glass on the roof and a fan at one end drawing moistened air through the house maintained a temperature up to 16° F lower than that in a similar house with all ventilators fully open and the roof shaded with whitewash. One interesting point which had not been so obvious in previous years was the effect of orientation ; a house with its longest axis approximately east–west was up to 6° F cooler than a similar house with its longest axis north–south.

The indoor mist propagation equipment has been increased and more kinds of softwood cuttings have been rooted than in previous years ; the ventilators in the propagation house have been screened with gauze to keep out insects which might infest material being propagated.

A small chamber in which the temperature could be maintained at a maximum of 75° F during the summer was built for use in apple scab studies. Some control of the humidity was also allowed by means of nozzles controlled manually. Although this unit was fairly satisfactory, some improvements, including automatic control of humidity, will be incorporated in the chamber before next season.

Because there are more workers in the virus glasshouses, the propagation of plants, particularly those from seed, has been reorganized and centralized. A chamber with supplementary light and heat has been built in one compartment to facilitate seedling production during the winter months.

During the exceptionally dry summer numerous repairs have been made to some of the glass-houses, insectaries and dutch light houses ; the opportunity was also taken to re-seal the roofs and sides of the dutch light houses to reduce drips to a minimum. Some urgent repairs to the roofs of the virus houses were also carried out.

In the summer of 1958 a few expendable pots of various types were tried with a view to reducing the labour involved in washing clay pots. A suitable type of peat pot has now been found, and more were used in 1959. At the same time different types of non-porous pot have been tried, the object being to reduce the number of waterings necessary. On a hot summer day there may be as many as three of these, so a reduction from three to one would constitute a considerable saving in labour. Being non-porous, these pots are also easier to clean than clay pots.

Trials with some rootstocks and small trees have been carried out to ascertain their suitability for repeated forcing. It was found possible to include two phases of growth in any one period of twelve consecutive months ; this result will lead to further tests.

Routine sprays are applied to all glasshouses except those in which insects are being raised or used for experimental purposes. Nicotine, karathane, endrin and TEPP are the main materials used, but recently the last has not appeared to be very effective against red spider and kelthane has been tried with considerable success. Outside, additional materials used include tar oil, lime-sulphur, DDT and colloidal copper.

Apple and pear trees have been chilled artificially and forced early in the year, and hundreds of rootstocks have been retarded up to July by keeping them in a temperature of 38–40° F until a month before they are required.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

The remarkably dry and sunny summer had several interesting features, notably the good size and yield of Cox's Orange Pippin apples. Nevertheless, on the most sandy and shallow soils, wilting and defoliation of some trees was seen, and the long-term effects have yet to be assessed.

Tree fruits

Rootstocks

The new semi-dwarfing apple rootstock M.26, which produces trees larger than those on M.IX but smaller than on M.VII, has been released for general distribution.

A trial comparing the anchorage of trees on M.II and MM.104, both staked and unstaked, was planted in an exposed position at the Institute of Horticulture, Pershore.

A rootstock trial of Bramley's Seedling was planted in Cambridgeshire, comparing the new rootstocks MM.104, 106, 109, 111, and M.XXV, with M.VII, M.I, M.II and M.XVI. Pollinator trees of Howgate Wonder on MM.104, 111, M.II and M.XXV are included.

Three papers on apple rootstocks were published (E501, 505, and 510).

In the pear rootstock trial yields were heavy, but fruit size was affected by the drought.

In the cherry rootstock trials, now three years from planting, trees on F5/4 shed their leaves markedly earlier than those on F12/1.

In the 13-year-old trial of semi-dwarfing plum rootstocks, trees of three varieties on St. Julien A carried the heaviest crops, and fruit size was above average. Cambridge Gage yielded best on Marianna.

Incompatibility

A 10-year-old incompatibility trial consisting of double-grafted trees of four plum varieties on Myrobalan B rootstock has been terminated and the results are being prepared for publication.

Histology

A study of skin-development in smooth- and russet-skinned apple varieties has been started. Preliminary studies of changes in skin colour following sun-dewing of apples have also been made.

Normal stem structure, and the changes preceding the formation of adventitious roots, have been studied in *Hevea brasiliensis* and other plants that do not root readily from cuttings or layers.

In fibre length studies of wood from apple and plum stems, differences of over 20% between strong and brittle varieties were found, indicating that this may be a useful criterion for estimating relative mechanical strength.

The relationship established for the Malling series between root structure and rootstock influence on the vigour and precocity of the scion, has been found to apply equally to the Malling-Merton rootstocks and the M.IX Crosses.

The structure of collenchyma cell walls has been examined in 1- and 2-year-old stems of apple seedlings differing in their degree of resistance to the woolly aphid. The results confirm previous findings that cell wall structure is closely related to resistance.

A study has been made of the development and structure of meristematic nodules that develop in young bud-unions.

Propagation

Experiments with hardwood cuttings and leafy cuttings under mist have continued in collaboration with the Plant Physiology Section. Cuttings collected and stored in autumn, lined-out in spring and budded that same year have produced moderately satisfactory maiden trees. A full-scale trial has begun with the apple rootstocks MM.104 and M.26, and the plums Myrobalan B and Brompton.

Further trials with leafy cuttings of rootstocks under mist show that rooting the cutting presents little difficulty, though growth is meagre in the year of rooting and a second year in the nursery is needed before the material is large enough for working.

Studies of factors that might affect the growth of buds inserted in apple rootstock M.26, have shown that cutting back the rootstock in February, April, or May, and disbudding at times varying from very early to late had relatively little effect on growth. Trees budded on 29th July 1958, showed less growth the following May than those budded on 26th August; and trees on rootstocks over 11 mm diameter at time of budding, less growth than those on thinner rootstocks. Both these effects tended to even out by the end of the season. These results probably explain the delayed bud-break observed in 1958 on trees on Lord Lambourne and Fortune, for those trees were both early budded and on thick rootstocks. In our 1959 nursery, trees on M.26 are as good as those on other rootstocks. The studies are being continued; meanwhile the precautions of budding M.26 in August rather than July, and avoiding very thick rootstocks for budding, can be recommended.

Testing rootstocks for propagation and compatibility continues. Cherry seedlings from some species crosses have been multiplied by layering and specimens of dwarf *Prunus avium* have been received from the John Innes Horticultural Institution. Our trials have shown that incompatibility symptoms in cherry are often long delayed and early grafting successes are to be viewed with caution.

Root studies

New research on seasonal development and functioning of the absorbing root systems of fruit plants has included studies of several techniques. Temporary root observation trenches were used to obtain valuable experience in observing root growth. To obtain information on the absorptive capacity of roots throughout the season, preliminary experiments with split root systems have been conducted. The cation exchange capacity of apple roots is also being investigated.

A paper on apple root growth in sward and clean cultivation was published (E514).

Pruning and tree shaping

In a trial of cherry tree forms, the trees high worked in the nursery before planting and those staddle worked when in their permanent positions are beginning to crop at the same time. Standard trees (with 6-ft trunks) have suffered some damage at the stake ties, in high winds, but bush trees with 3-ft trunks almost entirely escaped damage and are now so well anchored that the stakes have been removed.

A heavy crop of fruit was carried this year in the apple pruning trials. Some trees, especially on the light sandy Bearsted Series, bore fruit too small to market; trees under all three methods of pruning, established-spur, renewal and regulated, were affected. In these trials the fruit is left unthinned, and established-spur pruning is producing markedly larger fruits than either renewal or regulated pruning, with Worcester Pearmain and Laxton's Superb, though less so with Cox. Fruit thinning is evidently more important with the lighter pruning methods, especially in years of heavy fruit set.

A growers' bulletin on pruning Cox's Orange Pippin appears on page 122.

Fruit thinning

The collaborative experiment with the Plant Physiology Section on the thinning of Sunset apple was completed.

Analysis of fruiting

A trial comparing the effect of several growth substances, including gibberellic acid, on the setting of Cox showed no effect of the treatments. Comparative studies of spur development, flower condition and pollen tube development in trees of good and poor setting history of Cox's Orange Pippin have been started. Studies of factors that may influence fertility, such as the time of flower initiation, or a heavy crop in the previous year are being continued.

Biennial bearing

The trials in collaboration with the N.A.A.S. on the use of defoliating sprays have shown that more regular crops can be obtained in Laxton's Superb apple by spraying with 1½% copper sulphate in the 'off' year. The timing is critical, but even with inaccurate timing there is an improvement in total crop over the first two years. A report on the first two trials is in the press.

This year's trial of naphthalene acetamide as a blossom thinning spray was disappointing. Although fruit size was improved the yield was severely reduced. Treatments had a more severe

effect upon the trees this year than last, and this was apparent even before the drought. A trial of a new type of hormone for fruit thinning, hitherto used as a pollenicide, showed it overthinned at the concentrations used.

Staking and tying

In the staking trial with Czar plums all methods have shown some defects after three years. One patent tie seems better for plums than coir rope or string and sacking. It is clear that inspection and adjustment is needed several times a year, with all methods.

Weedkillers

A plot of apples and pears has been established for a trial of the persistent weedkillers monuron and simazine.

The effects of maleic hydrazide on apple trees are being studied by means of stem and soil applications to stocks and to grass around mature trees. The effects of diquat when applied to the stems of apple stocks are also being studied.

Breeding

Some 10,000 apple seedlings raised to produce new late flowering varieties were planted out during the spring. Since this programme was started six years ago, nearly 47,000 seedlings have been raised and some 2,500 of them have been kept for further trial. In addition, a few families have been raised to provide early maturing apple varieties and also russets of commercial value.

Selection of Mazzard (*Prunus avium*) seedlings as possible dwarfing and disease resistant cherry rootstocks has continued.

Varieties and clones

In the plum variety trial fruit size and quality were good ; yields of most varieties were moderate. Severn Cross was one of the few varieties badly affected by the drought. A heavy crop was carried, but the fruit was small and of poor quality.

A trial of Ellison's Orange apple trees, propagated from regular and biennial bearing trees, has been planted.

The bush peaches yielded well, Hale's Early gave 101 lb per tree, Libra 70 lb, and Peregrine 36 lb.

Intensive fruit

In the last two years the half acre of pyramid and cordon pears in Bradbourne Gardens yielded a total of 636 bushels ; and the $\frac{1}{3}$ acre of cordon and dwarf pyramid apples 479 bushels.

Small fruits

Variety and strain trials

Strawberries.—In a trial comparing spring and autumn planting of heat-treated and untreated clones of Cambridge Favourite and early Cambridge, the maiden crop of both clones of Favourite, autumn planted, was 25 cwt per acre. Spring planted plants bore much less—the heat-treated clone, whose vigorous plants were severely checked, bearing only 11 cwt and the untreated clone 15 cwt per acre. Fruits from the heat-treated clones were somewhat larger than from the untreated clones.

For the second consecutive year, a clone of Talisman containing latent virus has cropped rather more heavily than a completely virus-free clone.

In a trial comparing the healthiest available clones of eight varieties, Cambridge Favourite gave the highest yield, nearly 8 tons per acre. Merton Princess, in the virtual absence of *Botrytis* infection, yielded the most first-grade fruit, and the fruit was of much better appearance and flavour than in the wet season of 1958. Some blossom abnormality was seen in several varieties ; in Red-gauntlet, particularly, many flowers were small and contained abortive anthers, but nevertheless the crop was good.

Loganberries.—The most promising clones in a field trial of virus-tested plants grew strongly, and yielded about $3\frac{3}{4}$ tons per acre of exceptionally large fruit. A further field trial of virus-tested loganberries was planted comparing new clones with one from the earlier trial and a virus-tested sub-clone (LY.59) of the original East Malling selection.

Blackberries.—A small trial was planted to compare the growth and cropping of virus-tested clones of the Bedford Giant blackberry and one of its thornless sports.

Propagation and maintenance of stock

Strawberries.—Over 60 varieties and strains were maintained in an insect-proof glasshouse and in gauzehouses. Owing to the drought the yield of runners was generally poor, a notable exception being the heat-treated clone of Cambridge Favourite, M408, which did well.

Loganberries.—Two thorned and two thornless loganberry clones are being propagated for further trial.

Blackberries.—A virus-tested clone of the Thornless Oregon Evergreen blackberry—a sport from *Rubus laciniatus*—has been raised by leaf-bud cuttings. Three clones of Bedford Giant are being established in nursery beds.

Breeding

Raspberries.—Of the seven genes so far identified governing resistance to *Amphorophora rubi*, A_1 confers near immunity to strains 1 and 3 of the aphid and A_2 or the complementary genes A_3 and A_4 give high resistance to strain 2. These genes have now been transferred to inbred parent lines more or less true breeding for early-, mid- and late-season of fruiting. To obtain varieties resistant to all three strains of the aphid it is necessary to combine A_1, which was derived from Baumforth A, with either A_2 or A_3, from the American variety Chief. Plants carrying these combinations of genes were tested with the various aphid strains this year.

A fourth, very rare strain of *A. rubi* is now known to exist (see p. 32) and hybrid seedlings resistant to all four strains have been bred. Part I of a series of papers on the genetics of resistance to *A. rubi* was published (E.511), and Part II has gone to press.

Hybrid families raised with the object of transferring direct virus resistance from Newburgh to various parent lines, differed considerably in percentage of visible infection after being inoculated with viruliferous aphids.

Currants.—In breeding for improved strig characters, a black currant-red currant allotetraploid was successfully selfed and also backcrossed as male to Baldwin. Following intensive treatment with colchicine, a sterile F_1 hybrid of Baldwin × *Ribes longeracemosum* has set fruit from which seeds have been obtained. This is a first step towards transferring strig characters from *R. longeracemosum* to the black currant. Further backcrossing of *R. multiflorum* to red currant has been undertaken to obtain *multiflorum* strig characters in plants sufficiently close to red currant to produce satisfactory F_1 seedlings in crosses with black currant.

A search for sources of resistance to big bud mite (*Phytoptus ribis*) in *Ribes* species and hybrids is in progress in collaboration with the Entomology Section.

Gooseberries.—In breeding spineless gooseberries, a spineless triploid hybrid of 4*x* (black currant × gooseberry) × gooseberry fruited this season for the first time and further backcrosses to gooseberry were made.

Cultural measures

Strawberries.—Despite the severe drought, the small scale trial of Talisman yielded rather more from matted rows than from spaced plants, but in a similar comparison made with Cambridge Vigour and Cambridge Favourite, competition for water between plants in the matted rows severely reduced the yield of both varieties.

Black currants.—A new trial compares two degrees of pruning, hard and light, and two times, summer (post-cropping) and winter, with the varieties Mendip Cross, Wellington XXX and Westwick Choice. Four pruning trials have also been started in Norfolk, with the co-operation of the N.A.A.S. and growers.

Weedkillers

Strawberries.—CIPC at 1 lb per acre and propham at 6 lb per acre applied in November two weeks after planting reduced the maiden crop of Redgauntlet and Cambridge Favourite.

Black currants.—MCPB at up to 8 lb per acre in August again caused no serious damage. Simazine applied in November at 2½ and 5 lb per acre caused no reduction in crop and gave virtually complete weed control, except for bindweed (*Convolvulus arvensis*), for 12 months. Monuron at 5 and 10 lb per acre damaged the bushes and did not control groundsel (*Senecio vulgaris*).

Raspberries.—MCPB applied in August severely damaged only one unnamed variety (seedling 69/105) out of the six on which it was tested. No adverse effects were found after applications of simazine at 2½ and 5 lb per acre in November ; monuron at 10 lb per acre caused typical chlorosis of the leaves on the fruiting cane, but not on the young cane.

Frost damage investigations

There was little spring frost, but on two nights, May 4-5, and 5-6, when the blossoms of most apple varieties were in the petal-fall stage, the air temperature on our frost plot fell to 28° F, causing blemishes on fruits of many varieties. An automatically controlled sprinkler, starting at 32° F, operated on 11 nights, for 32 hours, while one starting at 29° F operated on 4 nights for 12 hours, thus using about 60% less water. Both protected James Grieve from frost rings and frost eyes.

On unprotected Dr. Jules Guyot, in the initial swelling stage, about 72% of the fruitlets were killed ; in other varieties 5-20% killing was found. On a maiden strawberry plot, Redgauntlet was more damaged than other varieties.

The autumn frosts of 1958 were used to test protection of black currants by sprinkling. The results need confirming under spring frost conditions. In order to have black currants flowering in the autumn, experiments in breaking the rest period were made. Gibberellic acid was found to cause bud-break within a week.

Gibberellic acid was also used alone and in combination with a growth substance on frosted and unfrosted apple blossom. This growth substance applied to apple blossom in the orchard gave seedless fruits of varying size according to the concentration used.

In the frost laboratory a Worcester sport (claimed to set parthenocarpic fruit), an ordinary Worcester and Kendal (a U.S. variety) were tested for frost resistance and ability to recover. Investigations of the frost resistance of apple seedlings were continued and a further test of frost resistance of peach blossom was made.

The study of some factors affecting hardening of apple blossom was published (E.502).

Mycorrhiza

Four different fungi have been tested for ability to form vesicular-arbuscular mycorrhiza in a range of host plants. It was found that *Endogone* sporocarps and some large soil-borne spores from Urbana regularly caused infections in a range of plants, and that cultures of *Rhizophagus* and *Pythium ultimum* did so occasionally. Infections caused by *Rhizophagus* and *Endogone* were anatomically similar, but were clearly distinguishable from those produced by *Pythium ultimum* or by the Urbana spores, at least in the early stages. *Pythium* infections became mycorrhizal only after a prolonged non-mycorrhizal phase in the root during which the vascular tissue was also penetrated, while in hemp *Endogone* infections approached a pathogenic condition with some penetration of the vascular tissue and formation of small lesions. These results were presented in a paper at the 9th International Botanical Congress.

A paper describing the external mycelium associated with mycorrhizal roots of fruit plants and recording variations in the number of connecting hyphae between roots and the soil is in the press.

Walnuts

Following a medium amount of blossom, yields were only moderate, but the nuts ripened well and were of high quality. Growth of the trees was exceptionally good in the hot, dry summer, and no symptoms of water shortage were seen.

Horticultural meteorology

Wind studies in orchards with differently spaced trees have been continued and a report on this work appears on page 52. The usual meteorological records were maintained. An experimental hail gauge was installed on the meteorological plot.

Publications during the Year

E477 Garner, R. J. (1958). **Propagation of woody plants by cuttings. Recent research and its application to fruit tree rootstocks.** *J. roy. hort. Soc.*, **83**, 335-43.

E499 ——— (1958). **Grafting established fruit trees.** *Comm. Grower*, No. 3569, 389-93.

E501 Preston, A. P. (1959). **Apple rootstock studies. Thirty-five years' results with Worcester Pearmain on clonal rootstocks.** *J. hort. Sci.*, **34**, 32-8.

E502 Head, G. C. (1959). **Some effects of temperature on the frost resistance of apple flowers.** *J. hort. Sci.*, **34**, 1-6.

E504 Knight, R. L., and Keep, Elizabeth (1958). **Abstract Bibliography of Fruit Breeding and Genetics to 1955. *Rubus* and *Ribes*—a survey.** *Tech. Commun. Bur. Hort. E. Malling*, 25, 254 pp.

E505 PRESTON, A. P. (1959). **Apple rootstock studies : growth and cropping of Cox's Orange Pippin on some Malling and Malling-Merton rootstocks.** *Rep. E. Malling Res. Sta. for 1958*, 47-52.

E506 DAVIES, MOYA H. E. (1959). **Some trials of the effect of defoliation upon cropping of apples.** *Rep. E. Malling Res. Sta. for 1958*, 53-9.

E507 ROGERS, W. S., and FROMOW, MURIEL G. (1959). **Royal Sovereign strawberry clone M.415.** *Rep. E. Malling Res. Sta. for 1958*, 60-2.

E508 TROWELL, G. F. (1959). **Weather conditions during 1958.** *Rep. E. Malling Res. Sta. for* 1958, 63-6.

E509 ROGERS, W. S., and BOOTH, G. A. (1959). **Irregular cropping of pears.** *Rep. E. Malling Res. Sta. for 1958*, 143-7.

E510 PRESTON, A. P. (1959). **Thirty-five years' results with three scion varieties on clonal apple rootstocks at East Malling.** *Rep. E. Malling Res. Sta. for 1958*, 148-50.

E511 KNIGHT, R. L., KEEP, ELIZABETH, and BRIGGS, J. B. (1959). **Genetics of resistance to *Amphorophora rubi* (Kalt.) in the raspberry. I. The gene A_1 from Baumforth A.** *J. Genet.*, **56**, 261-80.

E514 COKER, E. G. (1959). **Root development of apple trees in grass and clean cultivation.** *J. hort. Sci.*, **34**, 111-21.

II. STATISTICS AND RECORDS

Design and analysis

The designing of experiments continues at the usual level, but there has been a marked fall in the number of analyses of bodies of data, only 733 having been dealt with. However, last year the number was inflated by a back-log of analyses of chemical data ; this was cleared by use of the Elliott 401 electronic computor at Rothamsted. Also, during the year, in collaboration with the Forestry Commission Research Station at Alice Holt, a very general method of analysing data was programmed for the Pegasus type of electronic computor to provide a practicable method of carrying out analyses of variance whatever the experimental design.

Record Office

The work of cataloguing old trials has continued. Special attention has also been given to mapping soil variation over the Station. The acquisition of about 140 acres of Trust Land will call for further historical studies.

Statistical research

Methods of experimental design and analysis

The year has seen the publication of a further paper (M45) on the use of the same plant material for a succession of experiments. This completes a series of papers (M6, M22, M34, M39, M41) dealing with this subject. Another paper (M46) summarizes the whole series for the benefit of those who may want to use the methods without being interested in their mathematical bases. Work on this subject is for the moment in abeyance while further experience is gained of the methods already devised.

With the acceptance of these methods, attention is now being directed towards developing more generalized methods of dealing with data in which no assumptions are made as to the statistical design. A visit was made to the Mathematics Department of the University of Wageningen, Holland, to study the methods devised by Professor N. H. Kuiper and his associates. The contact has proved extremely stimulating and helpful, and some of the ideas that resulted are used in the programme for the Pegasus electronic computor referred to above.

Work has continued on designs involving unequal replication, and attention has also been given to the special statistical problems of small experiments. A further paper (M47) has been published setting out experience at East Malling in the practical designing of trials from 1953 till 1958.

During the past year the literature on stochastic processes has been studied. The general idea is of a process in which conditions at each stage result in part from conditions at a previous stage and in part from a random effect. Such an approach, it is now thought, may provide a basis for fresh studies of plant growth and population dynamics.

Allied to this, and also with consideration of small experiments, is the study of the application of sequential methods to orchard experimentation. If a trial has been carried out, and has inconclusively suggested a result, a further trial can be planned to take the matter further, the results of the first trial being considered along with those of the second. Such an approach is especially useful when experimenting or sampling is very laborious or involves the use of valuable plant material.

Statistical studies of biological problems

The fundamental difficulty of experimenting with fruit trees arises from the high natural variability of the material. This year has seen the completion of a large study on the reduction of variability in apple or pear experiments by calibration, an investigation that was speeded towards the end by use of the Elliott 401 electronic computor. The results suggest that it is often possible to halve the size of an experiment without diminishing its accuracy if adjustment is made for measurements made before the start of the experiment. Unfortunately the methods suggested are likely to be expensive in computing labour. A report is in the press.

The calibration studies on apples and pears have been extended to raspberries and black currants. As a preliminary to this a new way of assessing wood growth on black currants was successfully tried out (p. 67).

In this same problem of plant variability advances have been made in dividing the variability of size records, such as trunk girth, into components corresponding to various sources, e.g. initial size, planting effects, etc. A description of the statistical technique is in the press. Data from several apple trials have been passed to the Elliott 401 electronic computor in the hope of finding out which

of these components depend upon factors under the control of the experimenter. If any of the important ones can be controlled a useful advance will have been made. The earlier results are encouraging.

The records of the apple uniformity trial are now being studied, the first task being to trace changes in variability in the growing trees. In this study multivariate methods of analysis are proving useful, as in biometric investigations generally. Some examples of their usefulness have been published (M48).

In order to further the development of recording techniques, an attempt is being made to study the geometric form of the head of a tree in the hope of revealing relationships between its parts.

A paper (M49) has been published setting out the results of studies into the usefulness of branch girths ; in the past, reliance has been placed almost entirely upon the girth of the trunk. This paper is likely to be the last of the series (M17, M25, M30), because the methods used have now been largely superseded by multivariate analysis.

Field studies

The uniformity trial of apples has completed its third three-year cycle, and further trees are due to be lifted.

The investigation into methods of restoring soil uniformity has continued ; the indicator trees on the long-term rotation are now in their second year and have reached the stage at which the indicators on the short-term rotation were removed. Recent observations on residual effects in the nursery were published (M50).

Publications during the Year

M45 Freeman, G. H. (1958). **Families of designs for two successive experiments.** *Ann. math. Statist.*, **29**, 1063-78.

M46 ——— (1959). **The use of the same experimental material for more than one set of treatments.** *Appl. Statist.*, **8**, 13-20.

M47 Pearce, S. C., and Freeman, G. H. (1959). **A review of experimental design at East Malling, 1953-1958.** *Rep. E. Malling Res. Sta. for 1958*, 67-72.

M48 ——— (1959). **Some recent applications of multivariate analysis to data from fruit trees.** *Rep. E. Malling Res. Sta. for 1958*, 73-6.

M49 Holland, D. A. (1959). **Studies in the measurement of apple trees. IV. The use of branch girths to estimate tree size.** *Rep. E. Malling Res. Sta. for 1958*, 77-9.

M50 Thompson, J. A. (1959). **The occurrence of areas of poor growth in a fruit tree nursery.** *Rep. E. Malling Res. Sta. for 1958*, 80-2.

III. PLANT PHYSIOLOGY

With Professor F. G. Gregory's retirement in January 1959, the Research Institute of Plant Physiology of the Imperial College of Science and Technology was dissolved. Continuity of this valuable association, however, has been maintained, all but one of the Institute staff stationed here being appointed to the staff of the Physiology Section, thus permitting very close integration of the Section's research programme and continuing the trend of the last few years.

The distribution of dry weight in the tree

Growth analysis in terms of the increment in dry weight gives the best picture of 'growth' if efficiency of energy utilization is considered, and the distribution of this increment to the various parts of the organism is one definition of 'form', but inevitably under normal circumstances such analysis can only be carried out on small trees. From studies on this scale, relationships between parts of the plant can be worked out, and used in orchard-scale investigations. This year the following experiments were of this nature.

A comparison of leaf and root efficiency was made by drastically altering the proportion of leaf or root and observing the distribution of increment after treatment. Material had been prepared in the nursery by grafting together two rootstocks of M.XVI to form an inverted Y, and subsequently grafting on to the top a scion of Blenheim Orange. Maiden trees were pruned hard back and planted with each of the pair of root systems in a separate pot ; the scions made very good growth, and in mid-season treatments were applied : a longitudinal half of each leaf was cut off, one root system was removed, or both operations performed. Three weeks later a second set of trees was treated similarly. A preliminary examination of the results suggests that removing half the foliage has reduced the increment more than removing half the root system, and that either treatment resulted in a good deal of compensatory growth of the treated part.

A concerted attack on leaf area measurement by most of the staff made it possible to estimate *Net Assimilation Rates in young apple trees* over fortnightly periods. This short interval was used to reduce the changes in form with time, in particular the quality of the leaf surface. In one experiment Laxton's Superb was compared on the rootstocks 3431, M.VII and M.XXV, and in another trees of M.VII on the same rootstocks were compared under conditions of 'high' and 'low' nutrition. The results have not yet been analysed.

An interaction between the number of shoots on a young tree and the pruning response was indicated in an experiment mentioned last year (since prepared for publication), and was followed up this year. Alteration of the distribution of thickening on the main stem by *flexing* was attempted in a final experiment along the lines mentioned last year ; results are not yet to hand.

Growth of rootstock material under a range of conditions was required to determine how far variations in distribution of increment to leaf, root, new stem and old stem were associated with absolute differences in the increment. Conditions compared this year were frequent *versus* infrequent watering, high *v.* low nitrogen supply, and greenhouse *v.* open environment. Total increment was markedly affected only by the watering treatments, frequently watered plants being about twice the weight of infrequently watered ones, but all three sets of conditions caused differences in the distribution of increment to the various parts. In this experiment data on *water utilization* were obtained : water loss per sq. cm of leaf per day was nearly twice as great in the open as in the greenhouse, but within these two environments watering and nitrogen had little effect. On the other hand the amount of water used over the season to produce unit increment was little affected by environment or nitrogen, but was markedly affected by the water supply, the infrequently watered plants requiring about 20% more water per unit dry weight than those watered frequently.

An experiment has been prepared this year to evaluate *the importance of stem length in relation to tree growth.* To produce exaggerated differences stems from 3 to 12 ft long have been formed by inarching various numbers of potted layers one above the other on a tall framework. Three rootstock varieties were used. Observations will be made on the height to which a dwarfing rootstock can support growth, on the effects of spurs along the stem, and on the distribution of increment between leaves, new stem, old stem and root.

Growth and form in terms other than dry weight

Changes in the distribution of dry weight in the tree cannot always be followed, and observations in other terms have to be made ; these may be nearer to the usual concepts of growth and form in the sense that they record visual differences. In the experiment on *the effect of extreme pruning*

regimes and of deblossoming on growth, for example (planted in 1952/53), measurements are made of extension growth, girth, number of flower clusters, crop, etc. The behaviour of the Cox trees this year was interesting ; on most of the experiment, whether on M.IX or M.XVI, flowering was profuse but the set was poor, and a very light crop was picked. One group of trees, however, which has been deblossomed in previous years, this year was allowed to fruit, and here the Cox trees bore heavily, carrying 40 fruits to maturity from every 100 blossom trusses, compared with 8 on the trees which had cropped each year. The Laxton's Superbs carried a heavy crop, the lightly-pruned trees on M.XVI in particular bearing an excessive number of very small apples.

The nature of this experiment precludes thinning, but the *effect of hand-thinning on the shedding and final size* of Sunset apples was the subject of an experiment carried out in collaboration with the Pomology Section for a fifth and final year. An interesting aspect of the work was that early thinning (especially 14 days after full bloom) resulted in more extension growth as well as larger fruits.

Foliage development.—Extensive studies were begun this year of the development of the leaf surface in the orchard, basic knowledge of which is essential to many aspects of work at the Station. Leaf areas were measured at intervals on selected branches on trees in the pruning and deblossoming experiment mentioned above. While the lightly-pruned trees carried more leaves at first, by the end of June the heavily-pruned trees bore more and larger leaves per branch ; deblossoming increased leaf number and size from early in the season. These differences were accurately reflected in the increment in diameter of the branches, which may be a sensitive measure of leaf area. Other studies were made of sampling methods with the object of increasing the accuracy of estimations of total leaf area.

Net carbon dioxide uptake by individual leaves has been studied by means of the apparatus mentioned last year, which has been further improved. No differences in net CO_2 uptake were observed between leaves of a given scion variety on different rootstocks. The use of this apparatus has been extended, with promising results, to the measurement of gas exchange by shoots and small whole trees, by enclosing them in polythene tents.

The potential use of this equipment in assessing leaf ' efficiency ' was shown by comparing normal leaves with those bronzed by red spider mite : net CO_2 uptake by the latter was less. It has been claimed that photosynthesis can occur in bright moonlight, but no CO_2 uptake was observed under such conditions here.

Detailed studies of *the growth of individual shoots* were very limited this year. Some of the results mentioned in the last report were prepared for a demonstration on the modification of axillary branch form given at the 9th International Botanical Congress at Montreal ; one of the most curious features of axillary branch form revealed by the study of these data, was the pattern of internode length towards the base of the branches. In comparable material this year the same pattern was observed, and different but analogous patterns were found within each species, when naturally-occurring branches were examined on a few varieties of apples, cherries, peaches, and plums.

Spray damage investigations

Emphasis in this work has shifted from the immediate damage caused to leaves by given dosages of spray material to the longer term effects of spray damage, essentially employing growth analysis methods. This year experiments have been of a preliminary nature, and the results need confirming in more sensitive trials ; in particular the removal of spur leaves, so often damaged by lime-sulphur sprays, this season did not affect subsequent tree growth or crop. This is a most important point, and will be taken up next year on more suitable material than was available this year.

Carbohydrate resources

The serial sampling and analysis of trees of M.IX/IX and M.IX/XVI mentioned last year have been completed and published (p. 70).

Attempts to cause trees to use up their reserves of carbohydrates were made by shading or defoliation. Although big differences in growth were induced by these treatments, relative carbohydrate composition was little affected.

Trees have been prepared this year with two equal limbs, and will be used to test the interdependence of various parts of the tree with regard to carbohydrate resources by ' isolating ' different regions by ringing.

Natural growth substances

The growth inhibitor extracted from Myrobalan B shoots has not so far been identified, and another bulk extract was made this year by a rather simpler method, which allowed 56 kg of shoots to be dealt

with. It is hoped that new attempts at identification will be successful, since knowledge of the chemical nature might give some insight into the mode of action of this material ; at present we know only that extension growth of coleoptile sections is inhibited without affecting respiration, permeability of the protoplast to water, or the polar transport of β-indolylacetic acid. A report of these and other tests of this inhibitor has been submitted for publication.

As a preliminary to the study of the possible effects of roots on shoot growth by the production of ' regulating substances ', ether and water extracts of apple and plum roots are being examined by the coleoptile test for substances which promote or inhibit cell extension, to compare with the shoot extracts previously surveyed. Interesting contrasts are already apparent ; e.g. the neutral ether extract of plum shoots is quite inactive, but of roots is strongly inhibitory ; the acid fractions on the other hand are similar in both root and shoot. Apple roots, however, show no activity in the neutral fraction, while in the acid fraction there would seem to be marked differences between certain rootstocks, as there is also between the fine root and the thick. Both root and shoot extracts often contain an inhibitor of coleoptile extension which causes flaccidity of the sections ; this material, on circumstantial evidence, is very probably the glucoside phloridzin. A second inhibitor, which does not possess this toxic nature, has not so far been found in the root.

In water extracts of apple roots there would seem to be a third inhibitor which is not ether-soluble.

Publications During the Year

F102 Hancock, C. R. (1959). **Studies on extension growth in coleoptile sections. II. The effects of high concentrations of β-indolylacetic acid on section growth.** *Ann. Bot., Lond.*, N.S., **23**, 107-19.

F103 Barlow, H. W. B., and Hancock, C. R. (1959). **Studies on extension growth in coleoptile sections. III. The interaction of temperature and β-indolylacetic acid on section growth.** *J. exp. Bot.*, **10**, 157-68.

F104 Maggs, D. H. (1959). **The effect of the original situation of the scion on its subsequent growth.** *Rep. E. Malling Res. Sta. for 1958*, 83-5.

F105 ——— (1959). **The pruning response of one-year apple trees.** *Ann. Bot., Lond.*, N.S., **23**, 319-30.

F106 Hatcher, E. S. J. (1959). **Auxin relations of the woody shoot.** *Ann. Bot., Lond.*, N.S., **23**, 409-23.

F108 Purvis, O. N., and Hatcher, E. S. J. (1959). **Some morphological responses of cereal seedlings to vernalisation.** *J. exp. Bot.*, **10**, 277-89.

IV. BIOCHEMISTRY

Metabolism of the apple tree

Continuing the studies on the metabolism of phloridzin, an experiment was started by which it was hoped to measure the activity in apple shoots of the enzyme that causes the release of the bound glucose. In view of our preliminary observation in last year's report that this activity was apparent in summer but not in winter, it was proposed to measure the seasonal variation in activity. However, the activity of all the preparations has been very low and unexplained analytical difficulties that require further investigation have occurred.

Qualitative investigation of the changes which phloridzin may undergo have included the examination of the products arising from the treatment of the glycoside with acetone powder preparations of various apple tissues. In particular, preparations from fruit pulp (probably the only tissue devoid of phloridzin) had some glycolytic activity but caused rapid oxidation of the phenolic glycoside almost certainly as a result of polyphenol oxidase activity. Leaves (collected in September), however, had only slight oxidase activity but cause rapid hydrolysis of phloridzin and other β-glucosides.

Further work with the pulp tissue, i.e. a tissue devoid of phloridzin, has shown that it is unable to glycosylate either phloretin or quinol. However, some glycosylating mechanism does exist since, as is the case with many plants, phloroglucinol when supplied to the tissue is readily converted to its β-glucoside. On the other hand apple shoots, as well as glycosylating phloroglucinol will also form arbutin (not naturally occurring in the apple) from quinol, and this suggests that perhaps the mechanism responsible for glycosylation of phenols is more specific in the pulp of apple fruit than in the shoots.

In connexion with work on ' reserves ' in apple trees, the occurrence and metabolism of sorbitol is being studied. It has been confirmed that this sugar alcohol may be converted to starch in detached leaves, but the accompanying changes in other metabolites and the manner of the conversion are not yet clear. There has been some reason to suppose that the bark of trees might be capable of carbohydrate synthesis but in accord with other workers we were unable to confirm this during the summer months. Methods for the determination of compounds likely to be of importance in the accumulation and utilization of the energy reserves of the tree are being developed.

Host-parasite relationships

Attention has been directed to the mechanism of inhibition of *Venturia* spp. by different polyphenols and in particular the inhibition due to *o*-coumaric acid. This compound leads to an almost complete block of sporulation although the mycelium produced is about twice as great as that of the untreated control. Examination of the mycelium produced in the presence of *o*-coumaric acid revealed profound disturbances in the nitrogen metabolism and this in turn has suggested some possibilities as to the mode of action of the inhibitor.

Biochemistry of fruits

In collaboration with the Fruit Storage Investigation team and the Ditton Laboratory, work has continued on the metabolism of developing fruit. With last year's short series of experiments as a guide to sampling and methods of analysis, a full programme of examination of quantitative changes in individual organic acids in the peel and pulp of Cox's Orange Pippin apples grown under different cultural treatments was undertaken. From each treatment a series of samples was taken at intervals during growth on the tree from petal-fall to maturity. In each series an initial sample and samples stored at 12° C for various periods were analysed, the period being determined by the respiration rate of the fruit.

With a view to gaining knowledge of the mechanism responsible for acid changes in the fruit, especially during the critical stage of the respiration climacteric, the basic respiration and the respiratory response of discs of apple peel to the addition of various organic acids were studied in selected samples of fruit from the above experiment.

Since many of the analyses are not yet complete it is too early to draw any firm conclusions, but there are indications of differences in the respiratory response to added acids and in acid metabolism in fruit from trees receiving different cultural treatments known to affect keeping quality.

V. FRUIT NUTRITION

Soil moisture supply

In this exceptionally dry season, soil moisture decreased steadily after a warm moist April until the end of September, when the potential deficit reached 14 in. Tensiometers indicated severe drying to a depth of 4 ft under grassed trees by the beginning of August (see below under ' Soil management trials '), and soil moisture under mature trees was depleted to at least 4 ft 6 in. by the end of the season. Only the deepest soils could satisfy the water requirement of fruit trees without irrigation; some excellent crops were carried on such soils, in striking contrast with the serious drought-injury suffered by orchards with poor reserves of soil moisture.

Tree fruits.—The growth of the Laxton's Superb and Laxton's Fortune apple trees in the trials on the light sandy soil of Plot L7 benefited particularly from irrigation but neither variety carried a normal crop. For the first time since the trials were started in 1953, the unwatered control trees showed visible effects of moisture stress ; yellowing and defoliation began in August and defoliation of unwatered Laxton's Superb was complete before the most heavily watered trees lost any leaves.

The watered Cox's Orange Pippin trees in the collaborative trial at Luddington Experimental Horticulture Station showed a marked growth response to watering. Fruit size was increased, often unduly ; this is the result partly of young trees carrying light crops and partly, probably, of a high nitrogen availability in watered soil and of the high clover content of the swards where water has been applied. The storage quality of the fruit from the different treatments is being examined.

Small fruits.—Despite the dry season the unwatered control plots in the raspberry and black currant trials cropped well, nevertheless irrigation improved yields of Malling Jewel and Malling Exploit by about 35%, whilst yields from the Amos Black black currants increased by 40%. Fruit quality was greatly improved in both crops by irrigation. The straw mulch treatment increased the crop of the two raspberry varieties by about 20%. In both raspberries and black currants the amount and vigour of new growth made during the season was strikingly increased by irrigation, and it is already apparent that next year's crop on the unwatered plots will be low. Mulching was not successful in maintaining growth vigour this season since its effectiveness depends, very largely, on the conservation of summer rainfall.

An account appears on p. 78 of the practical value and construction of the soil moisture tensiometers used in these trials.

Mineral nutrition

Long-term factorial manurial trials

In both of the long-established manurial trials on apples the trees cropped heavily, despite the dry season. The 41-year-old Bramley's Seedling trees on one of the old rootstock plots (G 14) carried an average of over 1,000 bushels/acre, and this was even more remarkable in view of the moderately good crop of the previous year, following an ' off-year ' in 1957. Further, the fruit size was rather above average, being about equal to that of 1958 when the crop was smaller and the summer wet.

Drought symptoms were shown by many of the trees of Cox's Orange Pippin on M.XII in the manurial trial on Plot C2. The yellowing and early defoliation were confined almost entirely to the upper parts of the crowns of the trees. These symptoms occurred mostly on the plots that were grassed-down in 1953. The trees on the shallow soil at the western end of the plot were much worse affected than those on the deep soil at the eastern end, and this difference was reflected in the size of the fruit.

The weight of crop was greater on the trees in cultivated plots than on those in grass, the opposite effect to that recorded in the wet 1958 season. The reduction in the 1959 crop due to grass was very much greater in the absence of nitrogen applications. The crop records over the seven seasons since soil management treatments were superimposed on this manurial trial show that grassing-down has not reduced the total weight of crop where nitrogen is applied, in contrast with the serious reduction in the absence of added nitrogen.

A sample of fruit from each tree was graded for size and for type and severity of russeting. It was hoped to obtain information on the influence of nutritional factors on russeting, but the trouble was only slight this season. Fruit size was very variable, some trees carrying exceptionally large apples, and the mean size over the whole plot was well up to average, despite the heavy crop and the drought effects already noted. Storage investigations (p. 37) are continuing on fruit from this trial.

A new long-term manurial trial on pears at Efford Experimental Horticulture Station is being

sponsored jointly with Long Ashton. Trees of Conference and Doyenné du Comice, both on Quince A, with Williams' Bon Chrétien on Beurré Hardy on Quince A as guards, were planted in February and manurial treatments were started immediately. This is another factorial experiment, combining three levels of nitrogen with two of phosphate and two of potash, the lowest level in each case being *nil* ; provision is made for grassing-down half the trees at a suitable stage.

Nitrogen

Because of the great importance of nitrogen in fruit nutrition, differential nitrogen applications are included as treatments in many trials. In addition to the long-term manurial trials mentioned above, contrasting nitrogen levels are a feature of several field experiments on soil management and soil moisture supply. The results of these trials, and of work carried out elsewhere, increasingly emphasize the need for obtaining a better understanding of the nitrogen balance in orchards, with the aim of providing a sound basis for the efficient use of nitrogen in fruit growing.

In addition to studying the responses of fruit trees to different rates of nitrogen application, the form in which it is applied and the time of the application are also being considered. In a trial on cherries started in 1958, in which sulphate of ammonia is applied annually at 3, 6 and 9 cwt/acre, a comparison with ' Nitro-chalk ' supplying N at a rate equivalent to 6 cwt/acre of sulphate of ammonia is also included. A trial has been started at Efford Experimental Horticulture Station to determine the most effective time of application of nitrogenous fertilizers to dessert apple trees in grass. In this trial, three kinds of fertilizer are being used—acidic, neutral and basic—each being applied on six different occasions through the year.

Studies have been started of the seasonal trends of available nitrogen in orchard soils. Ammonium and nitrate nitrogen are determined (p. 21) on soil samples from grassed and cultivated plots, with and without nitrogenous fertilizers. Information on the distribution of mineral nitrogen throughout the soil profile at different times of year should assist in explaining the variable responses of fruit trees to fertilizer applications, especially when it becomes possible to relate such information to seasonal uptake by the tree (see also p. 21).

Attention is also being given to urea spraying in relation to fruit set (see below).

Magnesium

A paper is in press reporting the experiment in which magnesium-deficient dwarf pyramid Edward VII on M.VII were sprayed with 2% Epsom salt. Five post-blossom applications each year for five years resulted in a 70% crop increase, equivalent to an extra 775 bushels/acre over the whole period of the trial. There was little evidence of a growth response, and the number of fruit buds was not increased ; fruit size may have been somewhat greater, but the effect of Epsom salt sprays was largely due to an increase in the number of fruits. It is suggested that this improved fruit set was related to the prevention of early-season deficiency symptoms on the fruiting spurs.

The spray treatments in this trial were discontinued in 1959 and an assessment was made of the residual effects of the previous five seasons' applications on the current season's cropping and tree nutrient status. At the same time, a further trial was started on similar trees in the same plantation, to compare pre- and post-blossom applications, especially in relation to the setting of the fruit. This trial also includes an assessment of the relative efficiency of sprays of magnesium sulphate and chloride, an aspect which is also being studied on Crab C rootstocks, in both cases in collaboration with the Plant Protective Chemistry Section (p. 36).

Soil applications of Epsom salt, in the trials on apple rootstock stoolbeds, continue to produce only slight responses even though a total of 34 cwt/acre has now been applied and the ratio of ' available ' potassium to magnesium in the soil of the treated plots would usually be considered satisfactory.

A pot experiment was carried out in collaboration with the Plant Protective Chemistry Section to elucidate the observation that a reduction occurred in the percentage number of MM.102 rootstock shoots affected by apple mildew (*Podosphaera leucotricha*) after receiving sprays of 2% magnesium sulphate plus wetter.

The results of the spray culture experiments have now been assessed. The reduction in total plant dry weight due to magnesium deficiency could be attributed to the loss of photosynthetic leaf area by necrosis and leaf-fall. The form of mildly deficient rootstocks did not differ from that of healthy plants whereas severely deficient plants showed a higher shoot/root dry weight increment ratio. Magnesium moved preferentially to the apical leaves of deficient plants, but accumulated in the lower leaves when given in good supply.

A sand culture experiment has been carried out on 1-year-layers of apple rootstock M.VII grown in pots, using different levels of magnesium. By altering these levels during the season and by making

detailed leaf records, information has been obtained on the possible magnesium requirements of the leaf during its life.

Nutritional factors affecting fruit set

Arising from the work on magnesium, and the observation in one year that urea spraying also resulted in an improved set of fruit on the Edward VII trees, preliminary work has now been started on the relationships between nutritional factors in general and fruit set.

Detailed observations have been made on sample branches in several field trials involving contrasting manuring and soil management treatments, to determine the extent to which crop responses in the field are due to effects of treatments on fruit set or subsequent dropping of fruitlets.

Investigations on apple bark injury

The apple bark injury commonly known as ' pimply bark ' and ' bark measles ' has been induced in potted trees of Lord Lambourne and Cox's Orange Pippin. It is hoped that a knowledge of the conditions giving rise to the injury in the potted trees will help to indicate the cause of the same injury occurring in nurseries and orchards.

Soil management trials

Soil moisture tensiometers are installed at 8 in., 18 in., 3 ft and 4 ft depths under each treatment (grass sward, straw mulch, and clean cultivation with autumn weeds) in the soil management trial on dessert apples on Plot C11. The soil dried out uniformly down the profile under grass and straw mulch. Severe drying under grass occurred to a depth of 4 ft by the beginning of August. As noted above, the effectiveness of a straw mulch in conserving soil moisture depends upon periodic replenishment by summer rain ; in 1959, for the first time since the trial was started in 1951, considerable soil drying occurred to depths of 3-4 ft under the mulch. Least drying appeared to occur in the clean cultivated plots, in which the trees continued to decline. Under the other treatments, the trees, mostly in an ' off-year ', appeared little affected by the drought.

Three pairs of plots have now been grassed-down in the pilot trial in which close-planted cherries are grassed-down at intervals of one year over the range 2-7 years from planting. It is hoped that both this trial and the trial involving differential nitrogen applications on cherries will help towards the choice of suitable treatments for the soil management trial to be carried out on $5\frac{3}{4}$ acres of cherries interplanted with plums on Plot N2.

Progress in the trial on the restoration of uniformity of old orchard land is reported by the Statistics Section (p. 13).

Publications During the Year

U19 Greenham, D. W. P. (1958). **Problèmes de couverture du sol en culture fruitière basse-tige.** *Congrès intern. de Pomologie, Bruxelles, 40-4,* and *Le Fruit Belge,* No. 213, 65-9. (1959).

U21 White, G. C. (1959). **Recent thoughts on orchard nutrition.** *Comm. Grower,* No. 3322, 274-6.

VI. PLANT ANALYSIS

Studies on the mineral composition of apple plants

A paper has been submitted for publication on the uptake of nitrogen, phosphorus, potassium, calcium and magnesium by field-grown apple trees throughout one season. Two periods of special activity were distinguished, at the end of April and the end of June, when concentrations of the five elements changed appreciably over a short time in most of the tissues. These two periods coincided with the onset of rapid leaf growth (April) and of shoot growth (June). The uptake of most elements commenced at the end of April to May and reached a maximum at the end of July to August after which elements were lost from the tree mainly by leaf-fall ; uptake of nitrogen commenced about a month earlier. There is evidence of excretion of some elements through the roots. The concentration of nitrogen in the branches and trunk of the trees increased during the autumn but there was no net uptake of the element at this time, a fact that will be of interest to growers in view of the practice of applying nitrogenous fertilizers in the autumn. About 80% of the calcium in the structural part of the tree was in the bark, and 50% of the magnesium was in the leaves.

The results are now available from a sand culture experiment on apple rootstocks which were grown under highly contrasted conditions of nitrogen and potassium supply, 28 to 672 p.p.m. for the former and 15·6 to 624 p.p.m. for the latter. The treatments induced relatively small differences in growth compared with the much larger differences brought about in plant composition. The percentages of nitrogen and potassium in all parts of the plant were increased by increasing the level of supply of the respective nutrients while the others were kept constant. High concentrations of ammonium ions reduced the concentration of potassium in all parts of the plant. The concentration of calcium and magnesium in the plants varied inversely with the level of potassium supply, the effect on calcium being aggravated and that on magnesium ameliorated by a high level of magnesium supply (288 p.p.m. Mg compared with a normal level of 48 p.p.m.).

A long-term sand culture experiment has been started in which trees of Cox's Orange Pippin on M.VII are being grown in 40-gal. drums of unwashed Bedfordshire sand without through-drainage. The nutrient solution draining to the bottom of each drum is pumped off daily and re-applied to the surface of the sand, extra nutrients being added at frequent intervals. In this first season, all the trees have received the same balanced nutrient supply and have grown very well.

Leaf sampling

The results are available of an experiment on the effect of stock and scion on the mineral composition of apple leaves. Both scion variety and rootstock significantly affected the composition of leaves, though by no means similarly for the five elements N, P, K, Ca and Mg determined.

Leaf samples have been collected for the third year from 32 commercial orchards of Cox/M.II in Kent, Essex, Suffolk, and Norfolk. A report has been published (V4) on the mineral content of the first year's samples, and the 1958 data are now under consideration.

An investigation is being carried out on the possible relationship between the mineral composition of apple leaves from standard positions and the length of the lateral shoots from which they are taken.

Analytical methods

A paper is in press describing a rotating filter paper disc method for the spectrographic determination of boron, iron, manganese, calcium, and magnesium in solutions of plant ash.

A method has been devised for the estimation of total sulphur in plant material. Organic matter is destroyed by wet oxidation with a mixture of nitric and perchloric acids, the sulphur being converted to sulphuric acid without loss, provided an excess of perchloric acid is maintained. The barium salt is precipitated in a finely divided state in the presence of alcohol so that it readily dissolves in an excess of EDTA (ethylene diamine tetra-acetic acid disodium salt). Back titration with magnesium ions permits the EDTA equivalent of the sulphur present to be determined.

The analytical procedure developed by Allen (p. 116) has been adopted for the routine determination of magnesium.

Work has proceeded on chemical methods for the determination of zinc in plant material.

In collaboration with the Fruit Nutrition Section, a microdiffusion method is being introduced for the determination of ammonium and nitrate nitrogen in soils.

Analyses for other Sections

During the year some 2,000 samples have been analysed for other Sections, mostly for nitrogen, phosphorus, potassium, calcium, and magnesium, but including separate determinations of iron, manganese, and zinc. Assistance has also been given to the Plant Protective Chemistry Section with the determination of magnesium in large numbers of samples.

Publications During the Year

V4 Mason, A. C., and Whitfield, A. B. (1959). **A progress report on the mineral composition of leaves from selected apple orchards in the eastern counties of England.** *Rep. E. Malling Res. Sta. for 1958*, 86-8.

V5 Philcox, H. J. (1959). **A system of initial control for anode emission in a d.c. arc.** *Spectrochim. Acta*, **15**, 432-7.

VII. PLANT PATHOLOGY

BACTERIAL DISEASES

Bacterial canker of stone-fruits *(Pseudomonas mors-prunorum)*

As in previous years, streptomycin proved inferior to copper bactericides in the control of autumn canker infections. An early autumn schedule of Bordeaux mixture reduced the number of cankers in fruiting spurs, but not at nodes, compared with a combined spring and late autumn schedule. Fewest cankers were recorded on trees sprayed with colloidal copper, but this was partly an indirect effect, particularly with the spring sprays, of reducing the vigour of the tree.

Experiments were begun on the possibility of biological control by using a bacterium shown to inhibit infection by *Ps. mors-prunorum*. In a period of fourteen days after spraying on to cherry leaves numbers of the bacterium declined to approximately one-tenth the original level. During this period the natural population of *Ps. mors-prunorum* on the leaf surfaces remained fairly constant.

Fire-blight of pear *(Erwinia amylovora)*

All phases of this disease, including the overwintering holdover cankers, have now been reproduced by inoculations of pear trees in the glasshouse. Blossoms were successfully infected without wounding and within three weeks gave rise to extensive branch cankers.

Inoculations with different strains of *E. amylovora* into shoots, fruits, blossoms, and branches showed Laxton's Superb pears to be less resistant than Williams' Bon Chrétien or Conference. The apple varieties Spartan, MacIntosh, Winesap, and Cox's Orange Pippin were infected through blossoms with pear strains of the pathogen and detailed observations made of symptoms. Cox's appeared more resistant than the other varieties.

Pear isolates of *E. amylovora* were also shown to be pathogenic to plants of the following genera : *Crataegus, Amelanchier, Chaenomeles, Cotoneaster, Cydonia, Pyracantha, Sorbus.*

The morphology, physiology, and biochemical activities of several isolates of *E. amylovora* were compared in detail with two North American strains of the organism. No major differences were observed between the English and American strains.

Blossom wilt of pear *(Pseudomonas syringae)*

An epidemic of blossom wilt was studied in the spring of 1959, with particular attention to methods for distinguishing this disease from the early stages of fire-blight. Bacteriophages proved extremely valuable for differentiating quickly between the causal organisms.

Bacteriophages

Several bacteriophages active against *E. amylovora* and *Ps. syringae* were isolated from soils by a method previously described for *Ps. mors-prunorum* phages. In extensive tests with these and related bacteria the phages were specific for genera, but not for individual species. Methods were tested for the production of concentrated phage preparations. Titres exceeding 10^{10} phage particles per ml were obtained by flooding lysed cultures of bacteria with sterile broth and allowing the phages to diffuse into the broth. When the preparations were stored over chloroform at 0° C there was usually no loss of titre after a period of eight months.

FUNGAL DISEASES

Apple and pear scab (*Venturia* spp.)

Host-parasite relationships

Experiments in culture have confirmed previous indications of synergism between host phenolic metabolites as inhibitors of *V. inaequalis*. Experiments were begun to determine the effects of plant phenolics on the metabolism of this fungus. When *o*-coumaric acid was added to a liquid culture of clone E1 in active growth there were indications of altered nitrogen metabolism, the significance of which is being further investigated.

Progress was made in developing a method to separate the upper epidermis from the other tissues of apple and pear leaves, so that the pattern of host phenolics can be determined at the actual site of infection. The method has been used to study the quantitative and qualitative changes in phenolics after infection by apple scab and mildew, and also the phenolic patterns in a resistant hybrid of *Malus floribunda* × commercial apple.

Epidemiological studies

Collaboration has continued with Dr. J. M. Hirst (Rothamsted Experimental Station) and the Plant Pathology Laboratory, Harpenden, in the study of spore dispersal and climatic conditions suitable for infection. Scanning of slides from spore traps has this year been undertaken at East Malling. Ascospores were detected in late March and throughout April, but none after this month in spite of the occurrence of rain. Duration of leaf wetness was measured by a surface moisture recorder and the occurrence of infection periods computed in relation to temperature. The results were used as a basis for the timing of ' curative ' sprays in a field trial (see below).

An investigation of the development of perithecia in relation to ascospore discharge was begun. Experiments so far have been principally concerned with the effect of various fungicides on perithecial formation and ascospore production.

Glasshouse experiments on apple scab infection and control have continued on potted MM.109 rootstocks. Air-dried leaves as the source of ascospores proved much less prolific than hitherto and in several experiments the level of infection was low. Nevertheless, there was support for earlier findings that infection was not impaired when spore-contaminated leaves were allowed to dry for several hours before the infection period was completed by further wetting. The amount of infection was closely related to the method of inoculation ; fresh conidia in suspension, used as a spray, proved a convenient and satisfactory inoculum for studying the relative protective and curative action of various fungicides.

Field trials

Protectant and curative sprays for the control of apple scab were compared on Cox's Orange Pippin on M.IX. Seven protective lime-sulphur sprays were applied, twice before blossom, once during blossom, and four times afterwards at 12- to 14-day intervals. Curative sprays of phenyl mercury chloride (pre-blossom only) or of lime-sulphur were applied as soon as possible after infection periods but at a minimum interval of seven days. Nine curative sprays were given, three pre-blossom, one during blossom, and five post-blossom. Although unsprayed trees showed moderate scab infection, there was little leaf infection on any of the sprayed trees ; in the dry season of 1959, therefore, both methods were equally effective in controlling scab.

Apple mildew *(Podosphaera leucotricha)*

Following observations on the reduction of apple mildew infection by a DNC/petroleum spray at bud swelling (Report for 1958, p. 103), experiments were begun to determine the relative importance of the two components of the spray and of the timing of applications. Results indicate that both components are necessary for maximum effect and that the spray was more effective at bud-swelling than in the dormant period.

Microscopic examination of treated buds suggests that the spray acts not by eradicating the fungus, but by limiting its spread in infected tissues during bud-break.

Apple canker *(Nectria galligena)*

An account of experiments on control of canker by spraying appears on p. 85 ; further experiments have been started to compare fungicides on the basis of the spray programme suggested.

A bud-rot disease of hazel

Investigation into a devastating epidemic of bud rotting of cobnuts in a commercial plantation indicates that the causal agent is a fungus closely allied to *Gloeosporium* spp. Experiments to elucidate its annual cycle and develop means for its control are in progress.

Silver leaf *(Stereum purpureum)*

A technique has been developed for testing chemotherapeutants by injecting artificially infected trees.

A trial was started on mature trees to find whether removal of branches stimulated growth of the fungus in the tree.

Gloeosporium* diseases *(G. album* and *G. perennans)

The disease cycle

Traps designed to catch water-borne spores were used to estimate the number of spores present in an experimental orchard. The numbers fluctuated and were low during the summer, but by autumn

there was evidence of a general increase. Spore counts obtained by washing monthly collections of stubs in the laboratory followed a similar pattern. A parallel attempt has been made to relate spore production to periods of natural fruit infection in the orchard, but results from this part of the trial are not yet available. This work has so far been confined to *G. album* because of the difficulties of distinguishing spores of *G. perennans* from those of other fungi, a problem which is now being studied.

By modifications of Dr. Z. Borecki's original technique, a high production of spores *in vitro* of both *G. album* and *G. perennans* was obtained. These spores were applied to fruit samples from several commercial orchards prior to storage in connexion with the Fruit Storage Investigations (p. 37), in order to determine how far the numbers of spores in the orchards concerned affect the amount of rot developing during storage.

Control of *Gloeosporium* rots in store

In last year's trial cinnamic acid was less effective as a post-harvest dip than as a pre-harvest spray. In the 1958/59 trial the dip was therefore omitted in favour of a pre-harvest spray of copper-oxychloride in cotton seed oil. A single September application of this spray or of captan substantially reduced the amount of rotting compared with one of cinnamic acid, especially when the storage period was extended till February.

Verticillium* diseases *(V. albo-atrum* and *V. dahliae)

Host-parasite relationships in hops and other plants

Anatomical studies were continued, to elucidate the resistance mechanisms in a number of hop varieties showing the highest wilt tolerance so far recorded, and also in a series of crop plants and weeds ranging from very sensitive species such as potato to the highly resistant grasses. Suberin, apparently an important factor in endodermal resistance, is present in the hypoderm of many plants, e.g. *Solanum nigrum*, where it seems to contribute substantially to *Verticillium* resistance. Slight suberization of the hypodermis has recently been detected in a tolerant hop variety.

The role of phenolic substances in host-parasite relationships was investigated by chromatographic studies of the phenolic constituents of wilt-sensitive and tolerant hops, and by micro-chemical tests on the roots of about 25 species and sub-species of crop plants and weeds. Results so far suggest that *extreme* differences in wilt resistance between species may be associated with differences of phenolic content, but that intra-specific variations in resistance do not show any such relationship.

The phenolic constituents of the hop have not yet been identified, but certain known plant phenolics and their analogues have been tested *in vitro* and found generally to be inhibitory of *Verticillium* growth at high concentrations although stimulatory at very low concentrations. No difference in the response of fluctuating and progressive strains of the fungus was detected.

Perennation of *Verticillium albo-atrum* in the hop

Preliminary work indicates that there is relatively little direct connexion between woody tissues of the current year and those of the previous year, the new growth being supplied with water via new wood laid down in roots and main stock in the same year. It seems probable, therefore, that *Verticillium* present in wood vessels one year would not have simple and direct access to new vascular tissues in the next year, and this is consistent with the fact that plants showing disease in one season may not do so in the next.

Severe wilt in tolerant hops

Records from plots where severe wilt in tolerant varieties was extensive in 1958 showed a great reduction in wilt incidence during 1959, thus further strengthening the view that severe wilt in tolerants is probably related to environmental factors rather than to pathogenic variations in the fungus.

Tolerance trials in hop varieties

Routine testing of new hop varieties and experimental material from Wye College has continued.

Disposal of hop residues from infected gardens after machine picking (in collaboration with the Department of Hop Research, Wye College, and the N.A.A.S., Wye)

Investigations were started this year to determine the relative infectivity of the bine and trash fractions of machine waste with a view to estimating the risks of spreading *Verticillium* with these materials. Experiments connected with the possibility of eliminating *Verticillium* from residues by

composting are also in progress. The survival period of *Verticillium* in infected bine under heat treatment varies from a few hours to several days according to temperature.

Pathogenicity tests

Hop shoots rooted under mist have been successfully used for the rapid differentiation of progressive and fluctuating strains of *V. albo-atrum* by conidial inoculations. These small plants have proved very convenient for glasshouse experiments, with supplementary heat and light during winter months, and should enable fluctuating and progressive outbreaks to be distinguished in the year they are first observed.

Laboratory methods for differentiating tolerant and sensitive hop varieties

Experiments to explore the possibility of differentiating tolerant and sensitive varieties by inoculation of excised roots are still in progress.

Studies in the soil relationships of *Verticillium albo-atrum*

Mycelial growth in the soil.—A glasshouse experiment was made comparing mycelial spread of the pathogen in bare soil with that in soil planted with resistant and with susceptible host plants respectively, under conditions prohibiting any spread by the dissemination of conidia. The results supported the tentative conclusion from the earlier work with glass-slide root observation boxes, that such spread is limited to mycelial growth within the root systems of a sensitive host such as tomato. No mycelial spread occurred in bare soil or in soil planted with a resistant host such as a grass.

Survival in the soil.—Three different types of mycelial inoculum survived equally for at least 14 weeks in unsterile soils. A preliminary experiment indicates that conidia can survive for up to five weeks in unsterilized soil. Field experiments to test the persistence of *V. albo-atrum* in soils under various cropping and management systems have been continued. Some *Verticillium* still persists under grass cover and clean cultivation after three years but there are now indications that the best conditions for survival occur under annual weeds.

Effect of tolerant hop varieties on soil infectivity.—In an experiment where the tolerant variety 1147 was planted on land immediately after grubbing Fuggles infected with progressive wilt, the incidence of wilt in Fuggle N indicators, interplanted annually amongst the 1147, has remained at approximately 60% for three years. It seems clear, therefore, that a high level of soil infectivity is being maintained under the tolerant variety. Symptom expression on the tolerant variety during this period has fluctuated considerably.

Effect of fluctuating wilt on tolerant varieties

A trial to test the behaviour of tolerant varieties in a Fuggle N garden severely affected by fluctuating wilt was laid down in the spring of 1959.

Verticillium wilt of strawberry

Six strawberry varieties inoculated in 1958 were again kept under observation in the tolerance trial. *V. albo-atrum* has proved to be much more pathogenic to strawberry than *V. dahliae*, although the latter species is normally responsible for wilt in the field. Talisman has shown high resistance to both species, and Cambridge Vigour relatively low resistance.

FUNGICIDE INVESTIGATIONS

Concentrate sprays

A collaborative field investigation with the National Institute of Agricultural Engineering on the effect of droplet size and volume of lime-sulphur sprays on disease control on apples was concluded this year. At a constant dosage per acre there were no substantial effects on the control of scab and mildew by varying either the volume or the spray pattern within the limits investigated. These results are not regarded as conclusive, although they tend to confirm earlier observations.

On pears dilute hydraulic sprays were more effective than concentrates against scab on Williams' Bon Chrétien, and captan was safer than sulphur sprays, especially on Doyenné du Comice.

Systemic fungicides

Sodium cinnamate was at least as effective at 0·02% as at 0·2% in inhibiting scab when sprayed after infection of Cox shoots under glass. There was little evidence of systemic activity with sodium salts of cinnamic or *o*-coumaric acid in similar experiments in the field with M.III rootstocks. In the

field, but not under glass, there was evidence that the inclusion of glycerol in the sprays increased their effect.

VIRUS DISEASES OF FRUIT TREES

Apple

The virus causing stem pitting disease on some varieties of crab apple was found in several American apple varieties. An investigation (in collaboration with Long Ashton Research Station) was begun to identify the latent apple viruses that induce symptoms on peach, Virginia Crab and *Malus platycarpa*.

Pear

Death of young Williams' Bon Chrétien trees was found to be due to a virus carried without symptoms in the Beurré Hardy tree used for the intermediate scions (p. 104). This virus is probably responsible for the ' blister canker ' known for many years on young Williams' trees. A bark canker of Comice trees was also shown to be a virus disease.

A search was begun for a more sensitive virus indicator of pear viruses than the quince now in use.

Cherry

Two soil-borne viruses were transmitted to herbaceous hosts by sap inoculations from orchard trees infected with rasp leaf diseases. Raspberry ring spot virus was associated with some outbreaks of rasp leaf and raspberry yellow dwarf (arabis mosaic) virus with others. The identification of these viruses has been facilitated by the preparation of antisera from rabbits. The nematode vector, *Xiphinema* sp., was found in association with some infected trees and a related genus, *Longidorus*, with others.

In the field trials started in 1953, the yields of four varieties of cherry were again reduced by virus infection. Trees of Merton Heart behaved differently, however, and infection with certain viruses increased yield (p. 94).

Plum

Further tests confirmed that healthy scions had been propagated from previously infected plants of Common Plum, Marianna, Victoria and Ontario after heat treatment. The viruses concerned were those causing bark split, line pattern and peach green mottle (p. 99).

A virus producing fruit symptoms resembling ' plum pox ' has been transmitted by grafting to Warwickshire Drooper. This is the first confirmation of the virus nature of the disease in Britain, although symptoms have been observed in orchard trees for several years.

Virus-tested sources of scion varieties for the Mother Tree Scheme

Nine varieties of plum, three of cherry, one of apple and one of pear were added to the list of virus-tested material available for distribution. Further additions can now be made following the successful heat treatment described on page 99.

VIRUS DISEASES OF SOFT FRUITS

Strawberry

Investigations into the manner of spread of the soil-borne virus, raspberry yellow dwarf (arabis mosaic), showed it to be transmitted by a nematode, now identified as *Xiphinema diversicaudatum* (Micol.).

A virus complex causing symptoms similar to those attributed to soil-borne viruses was shown to be transmitted by strawberry aphids. The complex of at least two viruses produced crinkle-like symptoms on varieties known to be tolerant of the crinkle virus, but further work is needed to establish the relationship, if any, of the ' new ' viruses to those previously known to infect strawberry.

Investigations on the leafhopper-transmitted viruses of the green petal group have continued with particular reference to their range of plant hosts and vectors. Attempts to infect oat plants have failed ; oats can now be used with confidence for rearing non-infective leafhoppers and in tests for virus passage through the eggs of vectors. A virus producing symptoms similar to those of Stolbur disease was transmitted by naturally infected specimens of *Thamnotettix dilutior*.

Loganberry and blackberry

A field trial comparing infected loganberries (with a virus isolated from ' degenerate ' plants) with healthy controls showed that the virus reduces yield and vigour ; it is probably the cause of the degeneration of loganberries in recent years (p. 102).

Vigorous plants of Bedford Giant, Himalaya Giant, and Merton Early blackberries have been collected for virus tests and fruiting trials (in collaboration with the Pomology Section). All the Bedford Giant plants developed mosaic ; heat treatment has been used, followed by propagation from leaf-bud cuttings, in an attempt to obtain a healthy stock.

VIRUS DISEASES OF HOPS

Nettlehead

The search for the vector of the nettlehead virus has continued with emphasis on two lines of investigation, leafhoppers and nematodes. Two hop test-plants became infected after being infested with Cercopid hoppers collected from the vicinity of a persistent nettlehead outbreak. The three species involved are being tested in virus transmission experiments. No evidence of soil transmission was obtained. A survey, in collaboration with the Entomology Section, of nematode populations at five sites of persistent nettlehead outbreaks disclosed only a single eelworm of *Xiphinema* sp. and no other uncommon species.

A field trial was planted in a nettlehead site, using hop plants with either their roots or their bines enclosed in polythene. This trial was designed to provide critical information on whether infection occurs through the roots or the aerial parts of the plant.

Split leaf blotch

None of the six clones developed from Fuggle seedlings has proved sufficiently sensitive to be used as an indicator for split leaf blotch virus.

Mosaic

As Eriophyid mites failed to transmit mosaic virus, the hop-damson aphid has been retested in an attempt to repeat the results obtained in 1952 which indicated transmission by this insect.

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C413 ——— and ——— (1958). **Heat treatment for the inactivation of strawberry viruses.** *J. hort. Sci.*, **33**, 282-8.

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C416 Moore, M. H. (1958). **DNC-petroleum sprays help against apple mildew.** *Comm. Grower*, No. 3278, 870 ; *Grower*, **50**, 856.

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C430 Sewell, G. W. F., and Wilson, J. F. (1959). **Resistance trials of some apple rootstock varieties to collar rot (*Phytophthora cactorum*).** *Rep. E. Malling Res. Sta. for 1958*, 155-6.

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C432 Wilson, J. F. (1959). **Notes on three new wilt-tolerant hops.** *Rep. E. Malling Res. Sta. for 1958*, 161-2.

C433 Harris, R. V. (1959). **Progress in research on *Verticillium* wilt and virus diseases of hops in 1958.** *Rep. E. Malling Res. Sta. for 1958*, 165-7.

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VIII. ENTOMOLOGY

Natural control of orchard pests

A comparative study of the effects of two spray programmes on the fruit tree red spider mite, *Metatetranychus ulmi* (Koch), and its predators was continued for the seventh and final year. An abundance of the black-kneed capsid, *Blepharidopterus angulatus* (Fall.), resulted in mite populations being reduced to a very low level, comparable to the situation in 1956, and thus completing a second cycle in predator-prey interaction. A subsidiary experiment is also in progress to provide more detailed information on the interaction between predator and prey such as was reported above.

Following this study of the overall effect the emphasis is now shifting towards similar work on individual components of the spray programme, a start having been made to compare long-term effects on predator and mite populations of BHC-DDT and lead arsenate-nicotine when applied at the green-cluster stage.

The experiment to compare the effects of differential populations of both insect predators and *Typhlodromus tiliae* Oudms. on the fruit tree red spider mite has been concluded. With high insect populations, such as occurred in 1959, removal by hand was not found to be a very satisfactory method of regulating numbers. Nevertheless, the results have indicated that *T. tiliae* is more effective than insects in keeping populations of the fruit tree red spider mite at a low level.

The efficiency of sampling techniques has also been under review following a test of the knock-down method, reported on p. 109, in which the recovery of marked insects averaged only about 60%.

Biology and chemical control of fruit pests

Pre-blossom apple pests

Both the hatching period and the development of immature stages of apple sucker, *Psylla mali* Schmid., and winter moth, *Operophtera brumata* (L.), have again been studied under field conditions to provide information for the timing of spray applications. In a field trial, virtually complete control of the apple-grass aphid, *Rhopalosiphum insertum* (Wlk.), was obtained by a thorough hand-lance application, at the green-cluster stage, of demeton-methyl or ' Phosdrin ' at 0·006%, malathion or ' Rogor ' at 0·0125%, and a mixture of 0·01% γ-BHC and 0·05% DDT; BHC-DDT and ' Phosdrin ' were the most effective sprays against apple sucker. These results show that a wide disparity sometimes exists between the amount of toxicant required for control under experimental conditions and that used by fruit growers ; it also emphasizes the need for a full orchard-scale evaluation before experimental results can be translated into commercial practice.

Codling moth, *Cydia pomonella* (L.)

Assessment of adult emergence, by daily counts of pupal skins from overwintered larvae contained in corrugated bands placed in the orchard, has accounted for 94% of the moths leaving the bands. This method, requiring only a coarse mesh screen to give protection from birds, obviates the need for cages to ensure recovery of moths and thus provides conditions more closely approaching those forming the natural habitat. Further data on the flight period have also been obtained from daily captures in a light trap.

The results of a preliminary analysis of the effect of dusk temperature on flight activity have been applied to light trap catches obtained since 1951. There are indications that it may be possible to predict dates of adult emergence by the use of a heat summation method. Field observations on the relationship between the date of cocoon formation and onset of larval diapause showed that, even during the exceptionally warm summer of 1959, not more than 6% of the first generation pupated and gave rise to a second generation of moths.

In 1958 DDT, *O*-1-naphthyl-*N*-methylcarbamate and *O,O*-dimethyl-*S*-(4-oxo-1: 2: 3-benzotriazin-3-yl-methyl) phosphorodithioate gave better control than lead arsenate. High populations of red spider followed the use of DDT and the carbamate.

Fruit tree tortrix moths

Further information on the number of generations and flight periods of common species of fruit tree tortrix moths has been obtained from light trap captures. Inconclusive results were obtained from a field trial in which DDT was applied in mid-August against the summer generation of tortrix larvae and the second generation larvae of codling moth.

A species that webs together all the fruits in a cluster, and often burrows deeply into the flesh of fruits, has been under observation in mid-Kent orchards. The larvae occur in June and early July, and the life history and habits are very similar to those of *Pammene rhediella* (Clerck), but positive identification will not be possible until adults have been reared.

Fruit tree leafhoppers

Numbers of *Typhlocyba froggatti* Baker and *Erythroneura alneti* (Dahlb.) on apple have been assessed to observe any effects on the population arising from treatments applied in 1958. Overwintered eggs of *T. rosae* (L.) were collected from two sites to study the incidence of mymarid parasites.

Fruit tree red spider mite, *Metatetranychus ulmi* (Koch)

The orchard at the Essex Institute of Agriculture, where contrasting results were obtained with amiton and chlorbenside in 1958 (Q99), was used for a comparison between 2,4,5,4′-tetrachlorodiphenylsulphone, 2,2,2-trichloro-1,1-bis(*p*-chlorophenyl) ethanol, phenkapton and dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate, all formulated as emulsifiable concentrates. A single spray of each material, applied on 25th May, gave satisfactory control throughout the summer. The black-kneed capsid, the only predator present in numbers, was drastically reduced by the last-named chemical. This trial has also demonstrated that a chlorbenside-resistant population is susceptible to the first-named chemical which also acts as an ovicide and a larvicide.

Bryobia mites

The relationships between mites found on apple, pear, gooseberry, ivy, and grasses are being investigated by life history studies and host preference tests. Mites on gooseberry had one generation only, between March and June, whilst those on apple and pear passed through three generations ; all overwintered in the egg stage. In contrast, both adult and immature mites from grasses were observed overwintering in sacking bands on the trunks of apple trees.

Strawberry seed beetle, *Harpalus rufipes* Deg.

The life history of *H. rufipes* has been completed. Further population studies of this and other species of ground beetles have provided additional evidence that those adults responsible for damage invade strawberry beds shortly before the fruit begins to ripen. Aldrin, applied as a spray to soil around the plants at 10 lb/acre just before the blossom period or at 5 lb/acre immediately prior to strawing, greatly reduced fruit injury. The results of analyses for harvest residues are reported elsewhere (p. 34) ; samples of fruit were also processed for jam and the subsequent tasting tests indicated that this aspect would need further investigation before any risk of taint could be eliminated.

Black currant gall mite, *Phytoptus ribis* Nal.

A range of concentrations of fluoroacetamide and 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide, applied immediately before the blossom period and towards the end of blossoming, have been compared with endrin for control of *P. ribis*. Results will not be assessed until all the leaves have fallen. Analyses of fruit for harvest residues are being undertaken by the Plant Protective Chemistry Section.

Raspberry beetle, *Byturus tomentosus* (Deg.)

Following successful control with malathion of the leafhopper, reported by Dutch workers to be the vector of rubus stunt, the use of this chemical against the raspberry beetle has also been investigated. Two sprays, applied to loganberry in the second and fourth weeks of June, gave control at least as good as that obtained with the standard rotenone treatment, whilst with the individual sprays some infested fruit occurred respectively in either the late or the early pickings. Analyses for harvest residues are reported elsewhere (p. 35).

Laboratory studies of chemicals

Rearing test insects and mites

Cultures of winter moth, *Operophtera brumata* (L.), summer fruit tortrix moth, *Adoxophyes orana* (F.R.), the coccinellid, *Propylea 14-punctata* (L.), and *Drosophila melanogaster* Meig. have been maintained. Further progress has been made with codling moth and a method for continuous rearing in the laboratory has now been established. Two strains of fruit tree red spider mite, differing in their susceptibility to chlorbenside, have also been reared continuously but thriving colonies have proved difficult to maintain on apple due to severe infection of the host plant by powdery mildew.

Laboratory tests of insecticides

In collaboration with the Plant Protective Chemistry Section the persistence under orchard conditions of a wide range of chemicals, potentially useful against codling moth, has been determined. Both the toxicity to day-old larvae and the amount of toxicant present have been assessed

for deposits of varying age. The toxicity to young larvae which have already entered fruits has also been evaluated. Similarly, the persistence of DDT, lead arsenate and ' Phosdrin ' to newly-hatched winter moth larvae has been investigated, together with a study of the effect of these materials on larvae already present in buds.

As a guide to the selectivity of chemicals now under test for the control of various pests the toxicity of deposits on apple foliage to the commoner species of predators has also been investigated.

Two cultures of the fruit tree red spider mite, one derived from a chlorbenside-resistant population, the other from an orchard where this material had not been used, showed differences in susceptibility to chlorbenside shortly after the stocks were obtained but this was not apparent on re-test six months later.

Vectors of virus diseases

Leafhoppers

The life histories of *Aphrodes bicinctus* (Schrank) and *Macrosteles* spp. have been studied on their wild hosts in connexion with vector work on the green petal and allied viruses of strawberry. Similar studies of *Macropsis* spp. on *Rubus* have continued. The combined effect of chemical control of *Macropsis scotti* Edwards and removal of infected plants in two commercial plantations of cultivated blackberries has resulted in a decrease in the number of new infections. The Plant Pathology Section has been provided with insects for vector studies on hop, strawberry, and *Rubus* viruses.

Nematodes

A preliminary survey has been undertaken of nematodes associated with soil in the neighbourhood of virus infected plants of blackberry, cherry, hop, loganberry, raspberry and strawberry. *Xiphinema diversicaudatum* (Micol.) was recovered from six out of nine strawberry beds and three out of five raspberry plantations infected with arabis mosaic virus. From five cherry orchards containing trees with rasp leaf symptoms two yielded *X. diversicaudatum* and *Longidorus* sp. occurred in another. Identifications have been made for the Plant Pathology Section.

Host resistance

Woolly aphid, *Eriosoma lanigerum* (Hausm.)

The series of insectary screening tests, in progress since 1950, of apple seedlings raised to produce resistant scion varieties, have now been concluded. One hundred seedlings of parentage Cox's Orange Pippin × Northern Spy, found to be highly resistant in 1958, have maintained this status during tests in 1959. Histological studies have been continued by the Pomology Section in a search for factors conferring resistance.

Rubus aphid, *Amphorophora rubi* (Kalt.)

Field surveys and host preference tests have provided evidence that, in addition to the three strains already described (D317), a fourth strain exists on red raspberry in Great Britain ; only two appear to be generally distributed. Cultures have been maintained and, in collaboration with the Pomology Section, over 1,500 seedlings have been tested for resistance to one or more strains. Observations on the behaviour of aphids placed on leaves of a resistant variety, Malling Landmark, gave no indication that any external physical characters were present to prevent exploratory probing.

Nematode investigations

Root lesion eelworms, *Pratylenchus* spp.

To provide a source of inoculum, *P. penetrans* (Cobb) has been cultured on various hosts, the highest populations being obtained on celery seedlings.

The main work has centred on an assessment of the importance of *P. penetrans* in relation to other factors concerned in the replant problem. A pot experiment is in progress to investigate this aspect with apples. The occurrence in the nursery at East Malling of poor growth in both pome and stone fruits, where similar crops had been grown previously, provided further opportunities for surveys of nematode populations and an experiment has been started to determine whether the factors responsible for sub-normal growth can be eliminated from the soil by heat treatment.

Plots within a strawberry bed, heavily infested with *P. penetrans*, were grubbed, fumigated with a mixture of 1,2-dichloropropane and 1,3-dichloropropene or with 1,2-dibromo-3-chloropropane, and replanted with the variety Royal Sovereign. Plants grew best and nematode populations were lowest where the dichloropropane-dichloropropene mixture was used.

Systematic studies

Phytoptidae

Mites received from various sources have been identified, studies of those occurring in the British Isles have continued, and a list of British species has been compiled.

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D322 Briggs, J. B. (1959). **Methods for assessing resistance to *Amphorophora rubi* (Kalt.) in the raspberry.** *Rep. E. Malling Res. Sta. for 1958*, 121-6.

D323 Reed, W. (1959). **A preliminary study of lime-sulphur and other fungicides to *Psallus ambiguus* (Fall.) (Hemiptera-Heteroptera : Miridae).** *Rep. E. Malling Res. Sta. for 1958*, 127-30.

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IX. PLANT PROTECTIVE CHEMISTRY

Analytical methods

The bio-assay procedure, using *Drosophila melanogaster*, Meig., has been further improved for the measurement of sub-microgram quantities of several insecticides. This technique has been used to measure deposits on apple foliage of dimethyl 1-methoxycarbonyl-2-methylvinyl phosphate and of dimethyl S-(*N*-methylcarbamoylmethyl) phosphorodithioate, and harvest residues on soft fruit of aldrin, dieldrin, and a new chlorinated hydrocarbon which is also a cyclic ester of sulphurous acid, 6:7:8:9:10:10-hexachloro-1:5:5a:6:9:9a-hexahydro-6:9-methano-2:4:3-benzodioxathiepin-3-oxide.

Refinement of the chemical methods for use in the microgram range has been carried out for the insecticides, fluoroacetamide, diazinon, and the *O,O*-dimethyl and *O,O*-diethyl esters of *S*-(4-oxo-1:2:3-benzotriazin-3-yl-methyl) phosphorodithioate, and for the three acaricides FW293, 2-4-5-4′-tetrachlorodiphenylsulphone, and phenkapton.

Use of insecticides on top fruit

Pre-blossom application

Collaborative work has continued on the effects on beneficial insects of insecticides used for control of early-season pests of apples. Besides the established DDT/BHC mixture, attention has especially been directed to the performance of organophosphorus compounds, including malathion, demeton, dimethyl 1-methoxycarbonyl-2-methylvinyl phosphate, and dimethyl S-(*N*-methylcarbamoylmethyl) phosphorodithioate.

Codling moth

The performance of several insecticides of potential value against codling moth has been studied. The relative persistence of DDT and *O*-1-naphthyl-*N*-methylcarbamate as wettable powders, and of DDT, parathion, malathion, diazinon, 2:3-*p*-dioxane *S,S*-bis(*O,O*-diethyl phosphorodithioate), the dimethyl and diethyl esters of *S*-(4-oxo-1:2:3-benzotriazin-3-ylmethyl) phosphorodithioate and the cyclic organic sulphite mentioned above, all as emulsions, was determined on Worcester Pearmain fruit by field application and laboratory assay using chemical analysis and newly-emerged codling moth larvae.

The above chemicals (with the exception of parathion, diazinon and malathion which were considered to be less persistent than the rest) and lead arsenate were applied twice to two apple varieties, one early and one late, in the field at the recommended interval (3 weeks), and the residues at harvest determined. Residues from three applications of lead arsenate, at two-week intervals, were also measured.

Fruit tree red spider mite

In view of the remarkable tolerance exhibited to chlorbenside by mites in the experimental orchard at Writtle, Essex, it was decided to compare several alternative acaricides in this orchard. Amiton, which had given such outstanding control in 1958, was no longer available. However, fully adequate commercial control was given up to the end of August by *one* application on 25th May (well after petal-fall) of phenkapton (non-systemic but active against summer eggs as well as mobile stages), dimethyl *S*-(*N*-methylcarbamoylmethyl) phosphorodithioate (systemic but not ovicidal), 2:4:5:4′-tetrachlorodiphenylsulphone (ovi- and larvi-cidal) or FW293 (active against all stages). The results of this trial are very encouraging, and indicate that sufficient acaricides of differing modes of action are available to growers to enable them to use a three- or four-year rotation.

Use of insecticides on soft fruit

Strawberry

In field trials which confirmed that aldrin effectively controls seed-eating beetles, negligible harvest residues ($<0{\cdot}02$ p.p.m.) were found on fruit sprayed pre-blossom, and only $0{\cdot}05$ to $0{\cdot}1$ p.p.m. on fruit sprayed before strawing.

Black currants

Continuing interest in new chemicals for control of big bud mite has led to trials of fluoroacetamide and the cyclic organic sulphite mentioned above. Harvest residue determinations are in progress.

Loganberry

Following the previous season's work on raspberry, malathion has been applied to loganberry for control of raspberry beetle, *Byturus tomentosus* Deg. The half-life of the chemical applied at a dosage adequate for control was only 1 to 2 days, allowing an ample safety margin.

Fungicides

Glass-slide studies

It has been found, using copper sulphate as toxicant, that variation within tests is much less marked if the toxicant is added to fungal spore suspensions than if it is dried on the slide first and the spore suspension added afterwards. Studies with organic fungicides indicate that the former procedure gives greater apparent fungitoxic action, and all tests during winter 1958-59 were carried out in this way. A new formulation was used giving the following final concentrations in the toxicant-spore suspensions that were pipetted on to the slides: polyoxyethylene sorbitan monooleate, 0·005%, glycerol mannitan laurate, 0·01%, acetone, 1%; DNOP and all the purified dinitrophenols tested gave clear solutions at concentrations of 10 p.p.m. or less. Inhibition of germination produced by DNOP at 10 p.p.m. in different tests varied between 64 and 95%. *n*-Dodecylguanidine acetate gave complete inhibition at 5 p.p.m. but only 20% at 2·5 p.p.m. Actidione gave less than 50% inhibition at 5 p.p.m. At equimolar concentrations there was no difference in activity between DNOP and its *n*-octyl isomer, but the *cyclo*-octyl isomer appeared to be more active; the homologous series of *n*-alkyl compounds seemed to have very similar activity as far down as the butyl compound. Certain esters of DNC and some halogenated salicylideneanilines gave less than 25% inhibition even at 50 p.p.m.

Chemical control of powdery mildews

Studies with various chemicals, mainly dinitrophenols, have been continued on apple rootstocks and barley seedlings in the greenhouse. Shortage of M.III stocks made it necessary to work mainly with MM.106 and MM.109, and it was therefore possible to compare the reactions of these two varieties and, to a less extent, that of M.III. There was very little difference in the susceptibility of the three stocks under the conditions employed, but the protective performance of chemicals was almost invariably poorer on MM.109 than on MM.106; chemical determinations at the time of inoculation in one trial showed that slightly more chemical was present per unit area on MM.106 than on M.III or MM.109, but these differences were insufficient to explain the differences in protection.

Pre-inoculation infection was high at certain times in the season and a count of lesions was essential before the inoculation lesions were visible; however, adequate pre-inoculation infection enabled an assessment of curative action to be made, and the method could be adapted to studies of such action.

The marked degree of protection that is given on barley by certain cationic surfactants, especially with a cetyl chain, was not given, with possibly one exception, on apple. Chemical interaction of such compounds with dinitrophenols such as DNOP is to be expected ; certain mixtures exhibited reduced wetting action and the protection given was less than the sum of the protection afforded by each component alone. *n*-Dodecylguanidine acetate, which is very effective against apple scab, has surfactant properties but is not an adequate wetting agent on its own ; it gave considerable protection of barley against mildew, but no significant protection on apple.

Studies of isomers showed that protection of apple by dinex was superior to the 6-phenyl and even more so to the 6-benzyl compound ; damage increased in this order and all three compounds were very toxic to barley.

The settling-tower infection technique has been used, in collaboration with Fruit Nutrition Section, to study the effects of soil and of foliar applications of magnesium sulphate on the susceptibility of MM.102 rootstocks to mildew.

Phytotoxicity

The trial on Cox's Orange Pippin, Worcester Pearmain and Laxton's Superb designed to study the interaction of chemical type and order of application of fungicides has been continued. A remarkable effect of PMC applied pre-blossom (8th and 20th April) was seen on Cox's Orange Pippin ; besides leaf scorch, longitudinal splitting of fruit truss stems occurred, leading to wilting and fall of trusses and even of entire spurs. This may have been related to the unusually advanced condition of the foliage at pink bud.

Captan and *n*-dodecylguanidine acetate were again compared, both this year as 50% wettable powders, on seven newer varieties. On Early Worcester, the apples were fewer but larger on trees receiving captan.

On Lane's Prince Albert on M.VII, planted as maidens in 1953-54, the commercial 25% wettable powder based on DNOPC ' and related phenols ', at ½ lb per 100 gal., was compared with equivalent concentrations of crude DNOPC or the free phenol, DNOP, in an emulsifiable formulation, and with DNOP in an alternative formulation, at high and at low volume. *n*-Dodecylguanidine acetate 50% wettable powder, also included in this trial at 1 lb per 100 gal., gave excellent control of foliage scab but no control of mildew. All the other treatments, especially the DNOP formulations, gave marked control of mildew, and surprisingly large reduction of scab. No adverse effect on fruit set or cropping was apparent. Chemical determinations showed larger initial deposits of DNOP when applied with a paint-gun than at high-volume, but there were no differences between any of the treatments by the third day. Red spider records on 19th June showed only 5% or less of the infestation present on unsprayed control trees, but about 50% on the *n*-dodecylguanidine acetate trees ; an abundance of predators prevented further assessment.

Two post-blossom applications of PMC at 0·005% led to a reduction in the number of fruitlets formed per 100 fruit buds on Conference, Williams' Bon Chrétien, Laxton's Superb, and, especially, Doyenné du Comice. Re-wetting of leaves on five successive evenings failed to increase the damage. Chlorotic spotting of leaves was obvious on Conference and Doyenné du Comice, mild on Williams' Bon Chrétien and intermediate on Laxton's Superb.

No reduction of crop was caused by lime-sulphur, applied at 2·5% pre-blossom and 0·75% twice post-blossom, or by a commercial 25% wettable powder based on DNOPC, at 2 lb per 100 gal. pre-blossom and at 1 lb twice post-blossom, on the gooseberry varieties, Leveller and Lancashire Lad.

The single-leaf technique developed for studying the entry of copper into apple leaves has again been successfully employed for similar studies with magnesium salts. The more rapid and certain uptake of magnesium from the chloride than from the sulphate has been confirmed, and an explanation based on relative hygroscopic properties has been advanced. However, there must be other, at present obscure, factors which play a part in determining when leaves will take in magnesium. In trials in collaboration with the Fruit Nutrition Section, comparable reduction of deficiency symptoms appeared to be given by three applications of the sulphate at 2%, and by one application of the chloride at 1·6% (equivalent magnesium content) followed by two applications at 0·8% ; the chloride concentration was reduced because the first application caused damage.

Publications during the Year

Q97 Kirby, A. H. M., and Frick, E. L. (1958). **'Karathane'; the relative importance of the phenolic and unsaturated acid components in toxicity towards certain plant pathogens.** *Nature, Lond.*, **182**, 1445-6.

Q98 Kirby, A. H. M. (1958). **Organophosphorus insecticides.** *Rep. Prog. appl. Chem.*, 1957, **42**, 596-605.

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Q100 Allen, M. (1959). **Role of the anion in magnesium uptake from foliar applications of its salts on apple.** *Nature, Lond.*, **184**, 995.

X. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

Apple manurial trial

Results from the storage of Cox's Orange Pippin from the long-term manurial trials were in general agreement with those of the preceding five years' trials. Wastage due to *Gloeosporium* rots in storage at 37° F. was least on fruit from sward plots, and greatest in fruit from plots with applied nitrogen. The fruit grown in swards or with applied potash had the least low temperature breakdown in storage at 32° F. Losses through breakdown were higher in the fruit from plots with applied nitrogen except in clean cultivation. Comparable samples put in a scrubbed gas store at 38° F behaved similarly as regards rotting and showed no breakdown when examined in early February.

The rate of water loss per week at 40° F was recorded for fruit from all treatments in 1954 and again in 1958. In both years water loss was more rapid in fruit grown with applied nitrogen than without, but in 1954 the fruit grown with swards lost water more slowly than that grown in arable, whereas in 1958 the position was reversed and the sward fruit lost water more rapidly. This reversal may be due to the altering influence of the sward as it matures, or to effects of picking date in different seasons in relation to fruit maturity.

It has not yet proved possible to relate this storage behaviour with chemical analyses carried out at Ditton Laboratory, properties of the skin waxes examined at Long Ashton, or cell-wall constituents investigated at Leeds University. This season, in addition to these studies, a beginning was made by the Biochemistry Section in comparing the organic acids in fruits grown under contrasting treatments throughout the growing season up to picking time.

Time of picking

Early and late picked Cox's Orange Pippin apples were compared in storage at 32° F and 37° F with those picked at the normal time. The early picked fruit showed less wastage through *Gloeosporium* rots at 37° F, but breakdown at 32° F was worst on the early picked fruit and least on the late picked samples, even when these were held in store for the same period of time.

Fruit thinning

Sunset apples from a thinning trial were stored at 32° F and 37° F. The early thinning treatments and the more severe thinning produced very large fruits that kept badly.

Commercial samples

Owing to very severe hail damage in Sussex, two of the samples of Cox's usually stored were not obtainable. Interesting differences were obtained with the other samples stored at 32° F and 37° F, especially in their relative susceptibility to *Gloeosporium* rotting and to low temperature breakdown. These results are mainly of value in relation to the chemical analyses made on these fruits each year at Ditton Laboratory.

Survey of commercial fruit

Commercially grown Cox's Orange Pippin from many parts of the country were again stored at the Research Station in air at 36° F and in gas (3% oxygen and 5% carbon dioxide) at 38-39° F; they were examined on 19th January and 5th March respectively. In spite of running the cold store at 1° F lower than is usually recommended, few samples developed breakdown and the main losses were due to *Gloeosporium* rots. The running of the gas store for a fortnight longer than in previous years resulted in higher wastage from *Gloeosporium* rots. A number of growers co-operated by applying a differential application of nitrogen on two out of the four marked trees in an orchard, but the main effect of these applications may not show until the next season. There was general agreement between the results of this season's trial and those of preceding years in that the samples that kept best as regards bitter pit and breakdown came from orchards in grass, and those with the lowest wastage from *Gloeosporium* rots came from Norfolk and Suffolk, from young trees, and from the heavier soils ; captan sprays were valuable in reducing wastage by these rots. Many of the samples from gas store showed much core flush when cut a fortnight after removal from store, and no clear effects of

treatments were apparent at that stage. In general, large mature fruits tended to keep badly in every respect.

Leaf samples for analysis by the Fruit Nutrition Section were again collected in July from the marked trees in the selected orchards.

The first crop was harvested from the trees raised on M.IX in 1957 from selected scion wood of Cox's Orange Pippin.

Fruit development

Further work has been done on the rate and duration of cell division and cell extension in the developing apple fruitlet, and work has begun on the comparative development of fruitlets grown under various cultural conditions. Very severe blossom thinning was found to increase the rate of both cell division and cell extension in Miller's Seedling fruitlets, and cell division was found to continue for at least ten to twelve weeks after full bloom in the fruit from thinned trees.

Publication During the Year

T67 Montgomery, H. B. S. (1959). **Storage conditions in relation to *Gloeosporium* rots.** *Rep. E. Malling Res. Sta. for 1958*, 140-2.

XI. MISCELLANEOUS PUBLICATIONS

T68 Montgomery, H. B. S. (1959). **Russeting and cracking of Cox's Orange Pippin apples.** *Rep. E. Malling Res. Sta. for 1958*, 163-4.

T69 ——— (1959). **Progress in research in fruit crops in 1958.** *Rep. E. Malling Res. Sta. for 1958*, 168-73.

L32 Tubbs, F. R. (1959). **The living tree.** *J. roy. hort. Soc.*, **84**, 107-78.

Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

THE FAUNA OF THE ORCHARD

By PROFESSOR V. B. WIGGLESWORTH, C.B.E., M.D., F.R.S.

You must all have already a copy of Dr. Massee's book on *The Pests of Fruit and Hops*. There is, therefore, no need for me to emphasize the vast array of insects, mites, and spiders that are to be found on the trees and bushes of the orchard. In addition, there is a rich and complex fauna underground, ranging from the helpful earthworm, continually and unobtrusively cultivating the soil, to the troublesome nematodes that invade the roots of the fruit trees ; and a moving population of birds which are searching the twigs and trunks for insects or pursuing other less worthy aims.

But there is no doubt, I think, that we should all agree upon which is the most important central figure in the fauna of the orchard. That is certainly the fruit grower himself. In his endeavours to produce more and better fruit the grower is continually interfering with the rest of the fauna. And the purpose of this lecture is to reflect a little upon the significance of that interference.

Insects and mites were always a source of trouble for the grower of fruit. And the larger the orchards, the more pronounced this trouble became. The remedies employed—whitewashing, scraping, washing with simple chemicals, grease-banding—amounted to little more than tinkering with the orchard fauna ; and in some years the insect populations were appalling. Dr. Tom Wallace, speaking of conditions forty years ago in the Vale of Evesham (if I may be permitted to mention such a locality to the men of Kent and Essex), gave some indication of what conditions were like in an aphid year in those days. ' In many of the orchards, not only were the trees crawling with aphids but the soil under the trees was also green with the insects ; it looked as if moss was covering the soil. If you drove a car through the area on a fine day your vision was completely blacked out by dead aphids which had committed suicide on your windscreen, and you had to get out and wipe off the bodies. . . . In those days to visit plum growers during the period when aphids were hatching in the spring was almost a dangerous occupation.'

Then, in the early twenties, came the tar-oil washes—and the situation was transformed.

I am sometimes reminded, in this connexion, of the patient afflicted with trigeminal neuralgia, one of the most excruciating diseases to which the human flesh is heir. The sufferer is prepared to submit to anything to get rid of his pain. He will readily allow the surgeon to cut out the trigeminal ganglion—a formidable operation, for this ganglion lies in the skull right underneath the brain. And when he comes round from the operation—the pain has gone. He is prepared to lay half of all he has at the feet of the surgeon. Of course, the surgeon has warned him that the operation will necessarily lead to permanent paralysis of the cheek muscle on the one side ; but that is a little price to pay for such relief. However, as time goes on it becomes a little troublesome that food should collect between the gums and the cheek. Indeed, this becomes increasingly irritating—until, in the end, the excruciating pains of neuralgia are forgotten and no words are too bad to describe the surgeon who has caused him so much inconvenience !

Perhaps our attitude is a little like this when we complain of the evil effects of insecticides. The tar-oil washes did not clear up every trouble. The fruit tree red spider mite and the apple capsid raised their ugly heads ; and petroleum and DNC were in due course introduced into the spray programme. And so it has gone on ; as one insecticidal treatment has been introduced to cope with one problem, another problem has arisen. But, when all is said and done, the state of the patient is very different indeed from what it was at the time of the first world war.

According to Dr. Massee there are something like a hundred sorts of insects and mites inhabiting the apple tree. Most of these are actually feeding upon the tree and therefore, from the standpoint of the grower, ' doing damage'. But the great majority are so few in number that the harm they do

* The twelfth Amos Memorial Lecture, delivered at East Malling Research Station on 19th November 1959.

is insignificant. It is only a handful of species which are regularly present in sufficient numbers to be called ' pests '. All, however, are potential pests.

From time to time a new pest may be introduced or find its own way from abroad. (A few years ago, for example, we saw the arrival of the summer fruit tortrix moth, *Adoxophyes orana*.) But most new pests have been there all the time, living their own lives in their own quiet unobtrusive way. Then something happens, and what was merely an interesting insect becomes an offensive pest. I think the best way to appreciate the explosive nature of the situation in the orchard is to read Dr. Massee's ' Notes on Some Interesting Insects ' over the years. Every year you will find that some forgotten insect has broken through the cordon and for a brief period has flourished as a pest in somebody's orchard. (Dr. Massee does not reveal his inmost thoughts, but I sometimes feel that he gets a wicked satisfaction when some obscure insect momentarily gets the upper hand.)

It is not my intention to speak at length about the physiology of insects. But I would remind you that most insects lay several hundred eggs. Suppose the female of a given species lays 200 eggs on the average. Then it is obvious that if the population is to remain steady only two insects, one male and one female, must survive to the stage of sexual maturity, and 198 must perish. There is clearly an appalling rate of mortality.

It is impossible, with any given insect species, to know exactly how this total mortality (99% in the ideal example I have given) is made up. That must vary from year to year and from tree to tree. It is instructive just to observe with a hand lens a few twigs from the neglected apple tree in the back garden. They are teeming with life. Mites and mite eggs are on the leaves and small twigs. Typhlodromid mites are moving up and down in search of smaller mites to prey on. Here an anthocorid bug may be actually caught in the act of sucking up the contents of a mite egg. Everywhere small parasitic wasps (chalcids, ichneumonids, braconids) are running feverishly to and fro, searching for the caterpillars of the winter moth or the rare clusters of woolly aphid. In neighbouring trees, tits and other birds are diligently searching the branches for some purpose or other. Everywhere there are forces of destruction. If the pressure of these destructive forces is reduced, more insects will survive and the insect populations will increase, perhaps to the level of becoming a pest.

This situation is so complex and many-sided that it hardly seems possible to describe it in a few simple terms. But the scientist likes to have laws and classifications. Indeed, that is what he is paid to do—to describe everything in nature by means of the simplest possible laws and theories. One of the most helpful classifications of the factors regulating insect populations was drawn up twenty-five years ago by Harry Smith, of the Citrus Research Station in California. Smith divided the mortality factors into two main classes. (i) 'Density-dependent factors'—those which destroy a steadily increasing or a steadily diminishing proportion of the whole as the population increases in density. (ii) ' Density-independent factors ' which destroy more or less the same proportion of the population whatever the density may be.

To take a few examples : insectivorous birds will be among the density-dependent factors. In any one season the number of birds is fixed. Their appetites are limited ; moreover, they soon get tired of an insect that is too plentiful. So that the proportion of the insect population they destroy soon falls off as the density of the population increases.

Many insect parasites and predators and certainly insect diseases are density dependent in the opposite sense. The parasites and predators may themselves multiply rapidly and since the densely crowded insects are very easily found they tend to destroy a steadily increasing proportion as the population density rises. The same happens with infectious diseases of insects.

None of these factors is, of course, ' perfectly density dependent '. As Milne has pointed out, the only factor that is perfectly density dependent, in the sense that it acts more and more severely as the population rises, is intra-specific competition. For example, the competition for food among the members of a single species.

Examples of factors that are independent of density are adverse weather conditions, applications of insecticides and the like, which may be expected to kill more or less the same percentage of the population whatever the total numbers.

An immense amount of doctrinal argument has developed about this theory. In the controlled conditions of the laboratory, experiments can be so devised that the population is limited by intra-specific competition, and so illustrate beautifully the control of the population by density-dependent factors. Particular cases can be selected from nature where the unpredictable effects of weather are evidently more important in deciding the numbers of a particular species—and these weather effects may be acting either directly on the insect under study or indirectly by their effect on food supply or on enemies and diseases of one sort or another.

In fact, to the simple-minded observer the influences controlling survival (as well as those controlling rate of growth, rate of reproduction, etc.) are often so numerous and varied that the situation in nature may appear unpredictable.

In the ultimate limit it is the competition between the members of the species (for food and shelter) which limits their numbers ; but there is a broad range over which the numbers can fluctuate widely and often as the result of purely chance alterations in weather conditions, or the malign activities of the fruit grower.

The fact remains, of course, that density-dependent mortality factors *do* act like the governor on an engine (or what we should call nowadays a feed-back mechanism), and they do tend to keep the population within bounds and to bring the numbers down again if these bounds are greatly exceeded. And this balance is far more steady in those environments that are least disturbed by man. The numbers of the different kinds of insects remain tolerably steady in derelict orchards. But the fauna of the well-cared-for commercial orchard is very much disturbed by man. The grower generally uses density-independent factors, such as insecticides, for killing off those insects which he does not want. Here there is no feed-back mechanism, and such methods naturally cause violent fluctuations in the numbers of insects present.

That is how the biologist sees the orchard or any other community of animals and plants. Just a little persistent increase in the pressure upon a species and its numbers will fall ; a weakening or removal of some mortality factor and the numbers will rise. He feels that there is safety in numbers and variety. He likes to have a fair number of pest insects about in order to sustain a population of the parasites and predators which feed upon them. He feels that the presence of these is a valuable insurance against some unforeseen change that would otherwise lead to a great increase in the pest.

But there are many who find the biologist's way of looking at things rather woolly. They don't like the idea of having to be gentle with nature. They want to bludgeon her into subjection, rather than humour her and try to win her co-operation. The instinctive aim of the grower is, quite naturally, to make a clean sweep of the orchard; to exterminate the pest species from commercial orchards and hold them permanently in that state. Is this aim an impossible and unreasonable one ?

We must admit straight away that there is nothing wrong in principle with this idea. We do not tolerate in our beds a ' reasonable number ' of fleas, or a strictly moderate population of lice upon our persons. We expect to eliminate these insects completely from our homes and bodies. In many parts of the world the medical entomologist is aiming at the complete eradication of malaria-carrying mosquitoes. In the last few years American entomologists have eradicated from the whole of Florida both the Mediterranean fruit fly and the notorious screw worm fly. Why should the orchardist be satisfied with less ? Why should he be expected to harbour permanently a large number of pests and potential pests on his fruit trees ?

No one would venture to give a dogmatic answer. It may be that the time will come when man really will have tamed the earth. When wild nature as we know it will no longer exist and only a few species of plants and animals, chosen to suit the needs of man, will be permitted to exist within the few restricted areas of earth which break the universal desert of reinforced concrete.

But that glorious future has not yet arrived. We still have to compete with nature on something rather less than equal terms.

Now the key qualities of nature as seen by the biologist are variety and change. That was pointed out by Charles Darwin a hundred years ago. Darwin's doctrine of natural selection and the survival of the fittest was soon accepted. He had produced such massive and carefully accumulated evidence to support his theory. But Darwin himself was never satisfied. He was unable to get a clear conception of the laws of variation and heredity ; and he was never able to see evolution actually in progress. He got round this difficulty by supposing that the changes take place slowly over immensely long periods of time.

The irony of the situation was that within six years of the publication of the *Origin of Species*, Mendel published his *Laws of Heredity*, which provided exactly what Darwin had been looking for. That was in 1865. Mendel was familiar with Darwin's work, and was fully aware of the impact which his own discoveries made upon the idea of evolution. But so far as is known, he did not communicate with Darwin or send him a copy of his paper. Of course, Mendel did send out reprints. When I was working in Berlin in 1939, the botanist von Wettstein told me that when he was going through his father's library (his father had been professor of botany, I believe, in Vienna) he found a reprint of Mendel's famous paper, duly filed away. But it had failed to make any great impression.

It is ironical also that one of the most spectacular examples of evolution by natural selection was going forward under Darwin's eyes during the second half of the nineteenth century. I refer, of course, to the appearance of black moths in the industrial regions of western Europe. We now realize that these black moths were there all along. That is, an occasional one appeared from time to time, as an occasional albino may appear in man, but their proportion failed to increase. These black forms, however, are generally more hardy and robust than the paler forms, and whereas the pale forms are wonderfully concealed when they rest on the pale bark of trees covered with moss and lichens, they are at a serious disadvantage when the trees and fences are blackened, and the lichens killed off by the

pollution of the atmosphere. In recent years it has been proved experimentally by Kettlewell and others that the black forms do in fact survive the attacks of birds more successfully than the pale forms in the polluted regions ; whereas the pale forms are at an advantage on the uncontaminated lichen-covered trees. This process of selection has been going on at least since the middle of the last century. It continues with increasing intensity ; more and more sorts of moths are becoming predominantly black, and in some the caterpillars are becoming black also.

In the case of the black moths the pressure of selection is pretty intense, and the changes in the population take place with corresponding rapidity. But one of the most important developments in the past thirty years has been the demonstration, chiefly from the mathematical studies of Haldane and of Fisher, that a very small selective preference for one form will lead, surprisingly rapidly, to its becoming the predominant one.

The extraordinary efficiency of natural selection, and the existence of persistent inheritable changes within the species, the so-called ' mutations ', provide the background for our picture of nature at the present time. The great question is the origin of the mutations. Many of these are present all the time, but are concealed by being ' recessive '. They only become evident when the animals or plants are inbred for a number of generations. Other mutations occur anew. Whether there is a mechanism which provides that they appear when there is a need for them is highly dubious—although it often looks as though that were so.

Whether man, and in our present context that means the fruit grower, is evolving, is a matter for opinion and debate. But he certainly changes his habits, and such changes must affect the fauna of the orchard. The tar-oil winter washes of the early twenties were a great triumph. They virtually disposed of the insects that were most troublesome at that time, the mussel scale, the rosy apple aphid, the green apple aphid, the apple sucker, and gave partial control of the winter moths and their allies and the woolly aphid. But there were some insects and mites which they hardly affected. The eggs of the fruit tree red spider mite, the eggs of the apple capsid, and so on. At the same time they did kill off a number of predatory insects, anthocorid bugs, the black-kneed capsid and many more ; and they effectively cleaned up the bark of the apples trees, eliminating the lichens and mosses which provided a natural cover for many of the beneficial predatory forms.

Thus the fruit tree red spider mite, the apple capsid, the apple sawfly, the apple blossom weevil, became the important figures in the commercial orchards—and year by year new insecticidal formulations and new spray programmes were devised to cope with each new problem as it arose. I will not recapitulate the story as it developed in the late twenties, in the thirties and in the early forties. But what an opportunity for a Darwin : evolution going forward under more or less controlled conditions before our eyes.

Two main changes have come about. When I was first introduced to the commercial orchards —and that was by Sir Ronald Hatton and Dr. Massee in the early days of the war—I was disappointed by the poverty of insect life which they displayed. The number and variety of sorts of insects had been drastically reduced—but, as a corollary, the situation was in some ways potentially more explosive than ever.

The insects had not stood still under this treatment. We spoke of the moths of England becoming black under the impact of the industrial revolution. That really means that there were black moths in small numbers all along, but that under industrial conditions they have been selected out (and modified genetically in the process) so that they have become the dominant forms. As Kettlewell has pointed out, that did not invariably happen. Some species did not produce black mutants in time and were therefore exterminated from the industrial regions.

Similarly, we speak now of insects ' becoming resistant ' to insecticides. But all the evidence suggests that the varieties resistant to the insecticide in question were there all along. They have been preferentially selected out. In North America and elsewhere in the world where the codling moth is a serious pest of commercial orchards, it was controlled for many years by arsenical washes. But the number of these washes had to be progressively increased as the years went by, until it was necessary to apply seven or more in the course of a single season. They had been selecting out a strain which was perhaps able to avoid the arsenical particles when entering the fruit or was resistant to the poisonous action of arsenic.

When DDT appeared towards the end of the war, it seemed to provide the solution to this problem. It controlled the codling moth completely, after a single application. But in these same orchards the fruit tree red spider mite and the woolly aphid appeared in such quantities as had never been seen before. That, of course, was due to the elimination of their natural enemies under the action of the DDT. That result is still liable to occur ; but it is less dramatic nowadays, and the suspicion grows that DDT-resistant parasites and predators are making their appearance.

In this country we have not experienced quite such violent effects. Perhaps we are not so efficient or drastic as the Americans in the application of insecticides ; perhaps we are not quite so enthusiastic

for what is new. Whatever the reason, good or bad, we have tended to be a little more conservative and to do things a little more gently. But in all walks of life we are getting more and more Americanized. A few years ago we produced some magnificent bumper populations of the fruit tree red spider mite in Essex by the application of parathion in the late summer, when the population of predators ought to have been building up. And we have produced mites resistant to the summer ovicides chlorbenzide and others, with very creditable speed.

Meanwhile the insects change in other ways. The classic example is the apple capsid, which early in the century was found only on willow. Even when the branches of the willow tree mingled with those of the apple tree these bugs kept themselves to the willow and left the apple alone. Then, within a comparatively few years it became a serious pest of apple.

We are all familiar with the apple fruit rhynchites, *Cænorhinus aequatus* and the punctures which it makes in the apple fruitlets. The early stages of this weevil are normally passed within the fruits of hawthorn ; but in recent years it has been showing an increasing tendency to lay its eggs within the apple fruitlets. If we decided, for some reason, to eradicate all the hawthorn trees in the neighbourhood of orchards, perhaps we should be able to produce a form of *Rhynchites* which always bred in the orchard itself and thus provide the grower with a new major pest.

Indeed, it is impossible to read the ' Notes on Interesting Insects ' without being struck continually by the odd things that insects will sometimes do. How they will suddenly, for no apparent reason, change their habits, appear locally to breed in the orchards, where they have no business to be, and sometimes even to become pests for the moment. It may well be that we have here a ' biological race ', that is, a mutant form in which the change concerns not some attribute of structure or colour, but an alteration in behaviour. I notice that Dr. Dicker or Dr. Massee usually stamp out these interesting insects—but they serve to illustrate the point that the fauna of the orchard is in a continuous state of flux.

What of the present and the future ? In spite of everything that has been done during the forty-six years since Jesse Amos joined the Research Station at East Malling, the fauna of the orchard still presents us with a question mark. We are in a phase of intense activity and uncertainty. The initiative in the production of chemicals for the control of fungi and pests in the orchard has passed from the research stations to the large chemical firms in this country and abroad. These powerful new chemical materials are necessarily put upon the market, and come into the hands of growers, long before their long-term effects on the fauna of the orchards can be known. To elucidate these effects is a slow and difficult business ; and before it can be done the entomologist is overwhelmed by the arrival of more new products which demand assessment.

One thing is clear. The Research Station still occupies a key position in the scheme of things. Only the workers in the research stations are in a position to sort these problems out in an unbiased fashion. But they cannot do it in a day. The serious investigator cannot just hop like a flea-beetle from a problem here to a problem there, making no more than a minute puncture in each. He must make the difficult decision of what we really need to know, and then pursue that enquiry to its logical conclusion undisturbed by backseat drivers.

I hope I have said enough to make clear my opinion that the fauna of the orchard is still an immensely complicated problem. The grower has digged a pit for himself. He has educated the public to expect fruit of a quality which they never demanded in the past ; and yet the pests and diseases are not fully under control.

We have a fair knowledge of the general principles by which the fluctuations in the fauna are brought about. But the grower is like a boxer who is faced with an actual opponent. The general principles of pugilism will help him up to a point ; but no opponent is ever quite the same as the last ; the pugilist is dependent on quick thinking and past experience—guided by the general principles of his trade. The day when the orchard is really under control, and the fauna and flora will do the bidding of the grower, will come in time—but it has not come yet.

REPORT ON THE SOILS OF THE TRUST LAND

By B. S. FURNEAUX

In June and July 1959, a detailed field survey was made of the soils of the land purchased by the Trustees of the East Malling Research Station. This was carried out on precisely the same lines as that of the Station itself which was made in 1951 (1). In the 140 acres involved, borings were made in 239 locations, and descriptions of the soil recorded, although in many cases several borings were actually made in a particular spot in order to be sure that a true picture had been obtained.

Geology

Practically the whole area lies upon the outcrop of the Hythe Beds (Ragstone), but a small part of it extends on to the Sandgate Beds in the extreme north-west corner. When the Research Station land was surveyed it was found that these older geological formations contributed little material directly to the soil, because they are very largely covered by stretches of more recent deposits. This is even more true of the present land, in which only two borings encountered soil produced by the direct weathering of the ragstone and hassock beneath it. The land bears a close resemblance to that of the eastern half of the Research Station, the northern side of which it adjoins.

The soil is principally derived from two drift deposits ; river gravels and sands, and a heavier-textured material, containing numerous small fragments of chert, resulting from the solution of the limestone (the ragstone) beneath. Besides these there are some scattered patches of brickearth. The brickearth is, in fact, more widespread than the map of the soils might seem to suggest. Having been blown as dust by the wind during the closing stages of the Ice Age, it lies as a layer which varies from a few inches to several feet thick, on top of the other two drifts, in most cases contributing only to the surface layers of the soil.

Soils

With conditions so closely resembling those of the adjoining part of the Research Station it is not surprising that no soils were encountered upon the Trust Land which had not already been found upon the Research Station, and of the seventeen soil series mapped on the Research Station, only three, the Malling, Barming and Langley Series, make any significant contribution. Three others, the Chart, Wierton and Medway Series, occur in very small patches, while the Ditton and Bradbourne Series do no more than adjoin the boundaries.

This simplicity in the distribution of the soils is in sharp contrast to the great variety found in the northern and western parts of the Research Station, where to the greater number of geological materials is added the complexity afforded by the drifts laid down by the Millhall stream that flows past Bradbourne.

Where possible the borings were made to a depth of 62 in. and in a few cases this was exceeded by as much as 12 in. In some places, as might be expected of soils containing gravel, fragments of chert and ragstone, it was not possible to bore to the full depth of the auger, in spite of repeated attempts. Wherever it could be accomplished, however, the boring was made to the full depth, or to the solid ragstone where that lay closer to the surface than 62 in.

In a number of examples of the Malling, Barming and Langley Series no ragstone was encountered within 62 in., but in numerous other cases it occurred at shallower depths in all three. As in the survey of the Research Station, where the ragstone lay closer to the surface than 36 in., the soil was recorded as a shallow phase. As all the land lies well above the stream and the ragstone is freely pervious to water, all the soils examined were well-drained. In one place near the south-eastern extremity, two borings showed signs of iron-oxide deposition in the deeper layers which gave the appearance of having been caused by poor drainage. This lies close to an area of similar soil which was encountered during the survey of the Research Station when it was concluded that this represented a condition which had ceased to exist.

The river gravel soil overlying the Sandgate Beds in the north-west part of the land is also perfectly freely drained and belongs to the Barming Series and to its shallow phase.

Thus, employing the same classification as was used in the survey of the Research Station (1), the soils identified were as follows :

Chart Series.—Greyish, calcareous, medium to heavy loam, derived from the ragstone, in this case 16-24 in. deep. Well drained.

Wierton Series.—Lightish to medium loam passing into hassock (calcareous sand, tinged green with glauconite). Well drained.

Medway Series.—Deep, uniform greyish drift derived from the Hythe Beds : fine sandy loam to medium loam. Well drained.

The Malling Series

A section in the quarry adjoining the Trust Land, showing the well-structured drift soil overlying the ragstone. The dark layer of humus accumulation, known as 'pug' can be seen lying in contact with the upper surface of the limestone. It varies in thickness and in some places is almost absent, while its depth from the surface fluctuates with the uneven top of the ragstone. It can readily be seen how the depth of soil may vary greatly in quite short distances, while the shattered nature of the rock can also be seen, which enables roots to penetrate it. Between the layers of the hard limestone (ragstone) are the seams of calcareous sand known as hassock

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Malling Series.—Deep, warm brown drift over ragstone. Fine sandy loam passing into clay loam containing small fragments of chert, with a dark ' pug ' layer at the bottom. Well drained.

Malling Series, Shallow Phase.—As the last, but with ragstone occurring between 18 to 36 in.

Barming Series.—Deep, warm brown, light loam over ragstone, often gravelly, or with seams of gravel. Sometimes a stiff ' pug ' layer occurs in the lowest part. Well drained.

Barming Series, Shallow Phase (over ragstone).—As the last but with ragstone at less than 36 in.

Barming Series, Shallow Phase (over Sandgate Beds).—As the Barming Series but with Sandgate Beds, fine sandy clay, at less than 36 in.

Ditton Series.—Deep, warm brown light loam, similar to the Barming Series but with evidence of spring water seeping through the deeper layers of the subsoil.

Langley Series.—Brickearth. Deep, warm brown, mellow loam. Well drained.

Langley Series, Shallow Phase (over ragstone).—As the last, but with ragstone at less than 36 in.

Bradbourne Series. Deep, calcareous stream gravels, sands and silt with a permanent water table. Grey, fine sandy loam, to loam passing into yellow, fine gravelly sands.

The land

This is excellent farming land : it is easy-working, being mainly rather lighter than medium loam at the surface owing to the high proportion of fine grained sand that it contains. It is perfectly freely draining but, because of their loamy texture and good depth, these soils have a considerable capacity for the retention of moisture. It is perhaps their depth which is their outstanding feature, however. The great majority of the rocks in the south-east of England weather to produce soils that vary from 18 to 24 in. where they have not been subjected to much erosion. Here, only one boring showed a soil of less than 24 in. Even the shallow phases of the Malling, Barming, and Langley Series are in themselves soils of good depth ; they are called ' shallow phases ' purely to distinguish them from the normal examples of these Series, which are soils of great depth. In no fewer than 70 borings the ragstone or Sandgate Beds were not encountered within 5 ft of the surface, and it is probable that the number would have been greater had not stones prevented other borings from being carried to that depth. In the eastern part, in particular, the soil is especially deep, more than half the borings in Calves' Leys (O.S. 211), and Deadman Wood (Pt. O.S. 278) being 60 in. or more.

From the standpoint of laying out experiments this is a piece of land of an exceptionally high degree of uniformity. Except in two small patches, both of which lie near the boundaries of the land, only three soil series are represented, and these three are fairly closely related to one another and not dissimilar in many of their important characteristics. Besides this, however, the two principal series involved, the Malling and Barming Series, are distributed in fairly extensive stretches, which should greatly facilitate the laying out of experiments.

The survey of the soils undoubtedly shows that it is not only extremely good land for fruit growing, but that it is unusually well adapted for the accommodation of experimental plots.

Pt. O.S. 91. Palmer's Rough

Practically the whole of this field lies upon soil of the Malling Series of good depth : there are, however, two patches of the shallow phase, the larger one along the northern boundary, ranging from 18 to 35 in. in depth. In the smaller one, a little east of the middle of the field, the depth was 34 in. In the north-western part there is a small strip of the Barming Series.

It was noted that the surface soil contained a considerable amount of fragments of chalk, which must have been applied at some time in the past. These are likely to have converted a naturally mildly acid soil to a fairly high degree of alkalinity.

Pt. O.S. 213c. Wiseman (southern part)

The western two-thirds of this field lies upon the Malling Series, while the eastern third passes into the Barming Series, though in the middle of this there is an elongated patch of the Malling Series. The soil is mainly of very good depth and, of the 19 borings made, no fewer than 10 were 60 in. or more deep before ragstone was encountered. Nevertheless, towards the north-west corner the Malling Series becomes shallower ranging from 28 to 32 in.

Along almost the whole of the southern margin the soils of both the Malling and Barming Series possess a layer of mellow loamy material at the surface which is evidently of brickearth origin. In places this reaches as much as 36 in. deep, which brings the soil close in character to the Langley Series.

O.S. 213a. Wiseman (northern part)

The greater part of this field lies upon the Malling Series in which the depth over the ragstone ranges from 36 to more than 61 in. At the eastern end, however, the Barming Series comes in, being

from 53 to more than 62 in. There are also two smaller patches of the same series and one of the Langley Series, but all of these show considerable resemblances to the Malling Series surrounding them, so they do not indicate any great lack of uniformity.

It is towards the north-eastern corner that one of the few complexities of soil distribution in the whole piece of land occurs. There is a large and gentle depression in the surface which was probably caused by solution of the underlying limestone (ragstone) by water. Erosion of the rim has led to the production of shallow soils surrounding it, while the materials that have accumulated in the hollow show the influence of the calcareous ragstone from which they have been washed. This is a deep soil belonging to the Medway Series. Erosion has produced a strip of the shallow phase of the Malling Series 33 in. deep on the western slope of the depression, while on the eastern rim the Chart Series appears, with ragstone at 16-24 in. below the surface. There are numerous fragments of grey, calcareous ragstone lying on the surface in this area. Nevertheless, this complex area constitutes a relatively small part of the whole field.

O.S. 211. Calves' Leys

This is a remarkably uniform field of excellent soil. By far the largest part of it lies upon the Barming Series, and, out of the 30 borings made in the field, 17 showed the ragstone to be deeper than 60 in. Only in the south-east corner does the Barming Series decrease sufficiently to become a shallow phase at 30 in.

There are two patches of the Malling Series, that on the eastern boundary including a portion which just qualifies to be differentiated as a shallow phase because the ragstone was encountered at 34 in.

On the northern boundary brickearth makes its appearance, giving rise to a deep soil of the Langley Series. From this area the brickearth loam stretches out south-westwards, gradually becoming shallower, so that it contributes a mellow, loamy upper part to the soil of the Barming Series.

Pt. O.S. 278. Deadman Wood

Here again the Barming series predominates, though with two quite considerable areas of the Malling Series in both of which, however, most of the soil shows a sufficiently large proportion of river gravel material in the upper layers to bring it fairly close to the Barming Series.

This is a field of excellent soil of very good depth : out of the total of 30 borings made in it, 18 showed 60 in. or more of soil over the ragstone. Only on the south-eastern margin did the Malling Series shallow sufficiently in one small patch to produce a shallow phase of 34 in.

Towards the south-western part of the field the deeper layers of the soil of both Barming and Malling Series showed some staining with brown iron-oxide at depths of 27-38 in., similar to those normally produced in such materials by the passage of spring water. There appears to be little evidence to support the idea that spring water now seeps through the subsoil here and it therefore seems logical to regard this as a fossil condition. This lies close to the area that was mapped as the Ditton Series in Upper Grub adjoining, which is discussed in the report on the survey of the Research Station (1, p. 68).

Pt. O.S. 278. Upper Grub (eastern part)

This small triangular field lies mainly on the Malling Series, but this fades into the Barming Series in the south-west corner.

O.S. 84. Crab Tree (south-western part)

The greater part of this field lies upon the Barming Series which ranges from 41 to more than 62 in. in depth. The Malling and Langley Series creep into it from the northern and southern margins respectively.

O.S. 84 a-f. Crab Tree (north-western part)

Here again the Barming Series predominates, producing soils ranging from 41 in. to more than 67 in. in depth, but in three places towards the margins the shallow phase of the Malling Series appears in soils varying from 30-34 in. in depth.

O.S. 81. Crab Tree (eastern part)

The larger part of this field lies on the Barming Series, but from the south-east corner a strip of the Malling Series stretches across it, although the river gravel material in the upper horizons here brings it close in character to the Barming Series. In the north-west corner there is a small stretch of the Malling Series with a stiff, pale brown clay loam subsoil, unusually free from chert fragments. A good deal of the soil through the middle part contains some brickearth in its upper layers.

The depth of the soils is good ; only 1 boring showed less than 51 in. and 4 were 60 in. or more. This is very good fruit-growing land which exhibits a fair degree of uniformity.

O.S. 90 and 90a. Ditton Rough

The Malling, Barming, and Langley Series all take their share in the soils of this field. Very roughly, the Malling Series occupies the central part, with the Barming Series stretching around the margins, especially on the northern side. Patches of the Langley Series occupy the corners at the south-east and north-east and at the north-west.

The general depth of soil, though perfectly adequate for completely successful fruit cultivation, is considerably less than that of the land which comprises the eastern block of Ditton Court. Out of 45 borings only two failed to reach the ragstone within 60 in. Quite a high proportion of the soil of the Malling Series falls into the shallow phase, of which there is a long strip extending northwards from Egham Field and then swinging back in a big loop towards the south-west corner. Besides this there are two smaller areas, one of them flanked by a patch of the shallow phase of the Barming Series. Nevertheless, it must be emphasized that these soils, which range from 24 to 34 in. over the ragstone, are adequate in depth and are only shallow by comparison with the exceptionally deep soils that surround them.

In one place towards the north-eastern corner hassock, the calcareous sand of the Hythe Beds, appears at a depth of 18 in. and has weathered to produce a soil of the Wierton Series 46 in. deep over the ragstone. This is a very good soil of very limited extent.

It is perhaps worth noting that the strip of brickearth of the Langley Series, which stretches in a small valley right across Egham Field, extends into the south-east corner of this field and, as the valley itself gradually disappears, it too fades out, terminating in a shallow phase of the Langley Series, 30 in. deep over the ragstone.

O.S. 89 b-h. Scott (southern part) and Ditton Rough (extreme western end)

A block of the Malling Series, though approaching the Barming Series in its character in places, occupies the south-west part of this field. Most of the remainder lies upon Barming Series, although the Malling Series extends into it from the eastern side to produce a patch of the shallow phase 34 in. deep. In the north-east corner there is an area of brickearth of the Langley Series 52 in. deep. In general the soil is of good depth, ranging from 41 to 60 in.

O.S. 89. Scott (northern part)

The Barming Series gives rise to the soil of the largest part of this plantation, although there is a certain amount of brickearth in the surface in a number of places. This deepens and becomes more pronounced in a patch stretching from the centre towards the south-west corner : this transforms the soil into the Langley Series. Most of the soil is of very good depth, ranging from 48 to more than 66 in., 5 borings reaching 60 in. or more.

Stretching southwards from near the middle of the plantation and cutting across the arable strip, there is a very slight ridge, from which the land falls to the east and to the west. Here the soil shallows considerably and the ragstone lies at 30-31 in. Near the northern corner a strip of the shallow phase of the Malling Series extends into this field from the north-east, the ragstone being at 34 in.

O.S. 88. The Paddock

The whole of this field lies upon the Barming Series. In the southern part the shallow layer of brickearth, which occurs in O.S. 89 adjoining, extends into this block making the soil resemble somewhat the Langley Series.

A little south of the middle of this field the ragstone disappears beneath the Sandgate Beds. Along the south-eastern boundary beside the footpath these remain covered by too deep a layer of river gravel material to be reached, even by a boring made to a depth of 74 in., but throughout most of the northern part of the field they lie at 52-60 in. beneath a normal and well-drained soil of the Barming Series.

Along the western half of the northern boundary, however, the drift material decreases, so that the Barming Series becomes a shallow phase, 31-36 in. deep over the Sandgate Beds. The drainage remains free throughout.

It is very satisfactory to note that although this field is the nearest to the stream that runs through Bradbourne, the soil remains very uniform and is devoid of the complexities which were encountered in its vicinity on the Research Station land.

Reference

(1) Furneaux, B. S. (1954). The Soils of East Malling Research Station. *Rep. E. Malling Res. Sta. for 1953*, 60-82.

POMOLOGY

THE PERFORMANCE OF SOME VIRUS-TESTED LOGANBERRY CLONES

By A. BERYL BEAKBANE and M. V. LABERN

The plant which eventually bore the name Loganberry was selected in 1881 by Judge J. H. Logan, from open-pollinated seedlings of the common wild dewberry of California, *Rubus ursinus* Cham. & Schlecht. In vegetative characters it resembled the dewberry, except that it was more vigorous, but its fruit was like the raspberry in colour and in certain other characters. The new fruit was presumed by the raiser to be of hybrid origin, and this was subsequently confirmed by Crane (4) in breeding experiments. A clonal race from the original seedling became widely grown as Loganberry. In the course of time, variation has arisen both by the inclusion of seedlings and by mutation, and a number of types now exist which, though basically similar to the original Loganberry, differ from it in certain characters. Clearly the name Loganberry has now lost its status as referring purely to Judge Logan's original plant and its clonal race, and distinguishing names or numbers will have to be given to selections within the loganberry group which has evolved from the original hybrid.

At one time the loganberry was more important among the commercial soft fruits than at present, but low yields and poor fruit quality among other factors have led to a reduction in the acreage of this crop. The planting of weak or less productive variant types (2) may have been partly responsible for the low yields, but even types closely resembling the true Loganberry frequently proved to be uneconomic. For example, by 1954 the fruiting stock in the Wisbech area had deteriorated drastically, and certain cultural experiments with loganberries at East Malling were discontinued on account of poor cane growth and low yield.

In an attempt to improve the position, vigorous strains of loganberry were obtained from various sources, enabling two lines of work to be initiated : firstly, the selection of different loganberry types with a view to improving on the existing Malling clone ; and secondly, a study of the health status of these and other commercial stocks of loganberry including the Malling clone selected in 1932.

Work on the health status of these clones was undertaken by the pathologists at East Malling, and this has been published separately by Legg (6). He identified a virus in some of the ' degenerate ' clones but found no evidence of virus infection in 10 vigorous clones examined.

Comparison of virus tested clones

Material

In view of the urgent need of the industry for improved planting stock, the first five clones to pass the virus test were multiplied by tip-layering for immediate field test. All five resembled the original Loganberry in vegetative features, but one of them differed from it in certain flower and fruit characters, and in time of leafing out. One of the tested clones, 579/1, came from Auckland, New Zealand ; the others came from Eire—460/2 and 461/1 from Tipperary, 463/3 from Limerick, and 578/1 from Co. Carlow.

Layout and management

The trial, comprising 20 replicates of single-plant plots arranged in randomized blocks, was planted in March, 1956, at 8 ft × 7 ft 6 in. spacing, with rooted tips lifted direct from a tip-layer nursery without being ' bedded ' for a year.

The canes were supported on wires at 3, 4, 5 and 6 ft above ground level, the young cane being taken vertically up to the 5-ft wire, then divided and tied along the 6-ft wire. The advantages of this method of training the young cane have been described by Beakbane (3), and Moore (7) subsequently reported that one of the most outstanding results of his trials on the incidence of cane spot on loganberry was the high yield of plants in which the young cane was trained *above* the fruiting canes. Each spring the cane was removed from the 6-ft wire and trained in a fan shape on the 3-, 4-, and 5-ft wires, the ends being pruned to ensure that the canes did not project more than 6 in. above the 5-ft wire (Figs. 1 and 2).

The choice of a training method for the fruiting cane was largely determined by the relatively small area available for setting out the cane in a close-spaced design, and by the need for separation

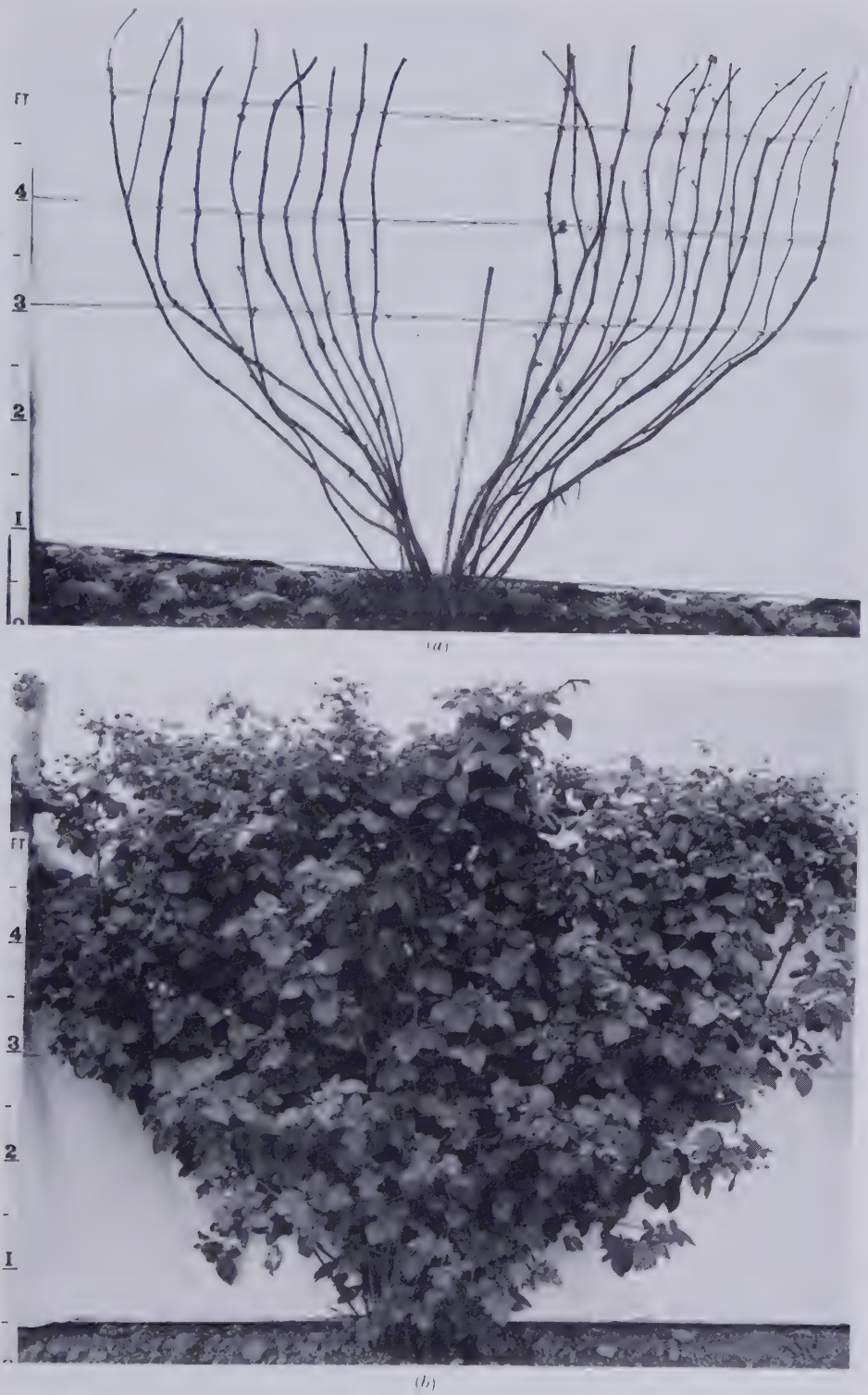

Fig. 1

Four-year-old plant of clone 463/3, (*a*) in early spring, (*b*) in summer, demonstrating the vigour and productivity typical of the clone, and illustrating the fan method of training

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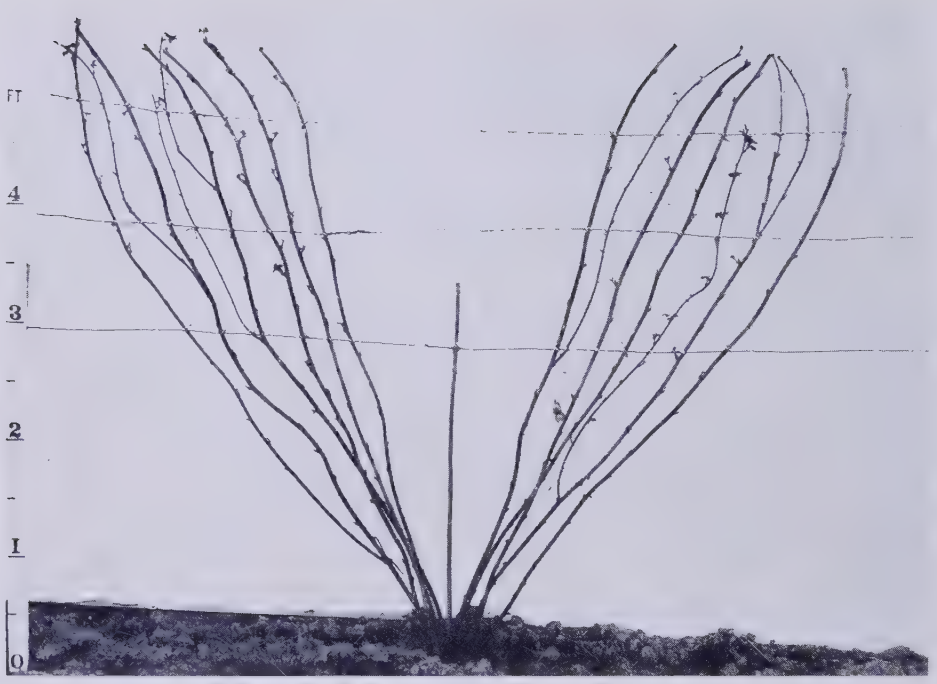
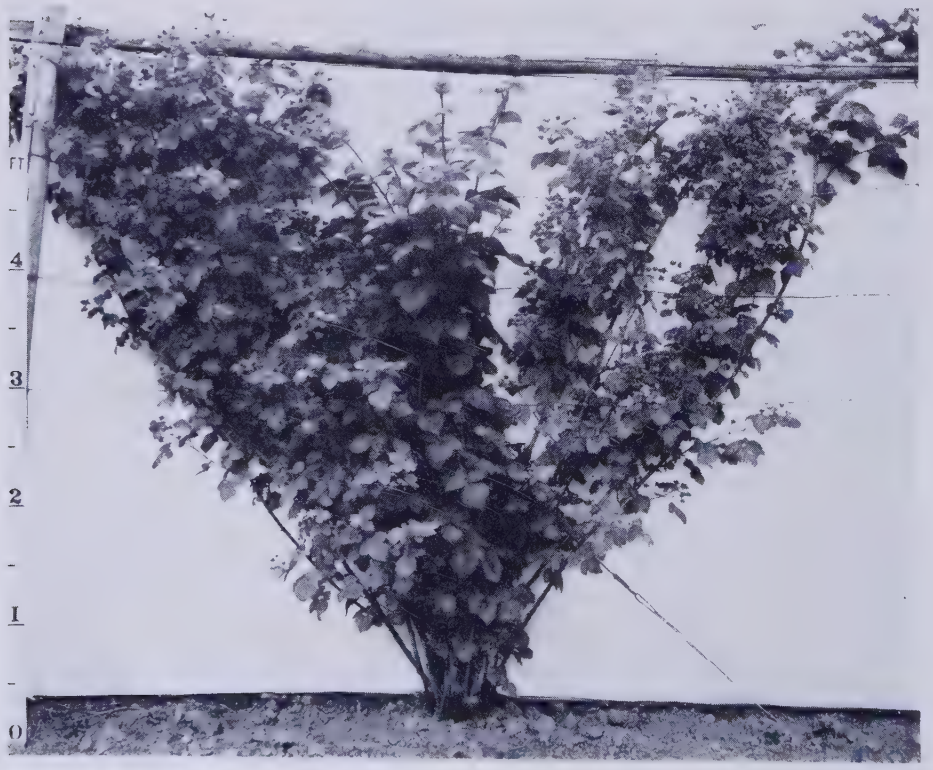


(*a*)



(*b*)

FIG. 2

Four-year-old plant of clone 578/1, (*a*) in early spring, (*b*) in summer, showing the relatively weak growth of this selection

FIG. 3

Lateral shoots photographed in July, 1958. The shoot on the left is undamaged. The primary bud (*p*) of the shoot on the right was killed by frost. A secondary lateral (*s*) bearing a flower bud (*f*) was produced later in the season from the damaged node. The delay in fruiting of the secondary lateral can be clearly seen

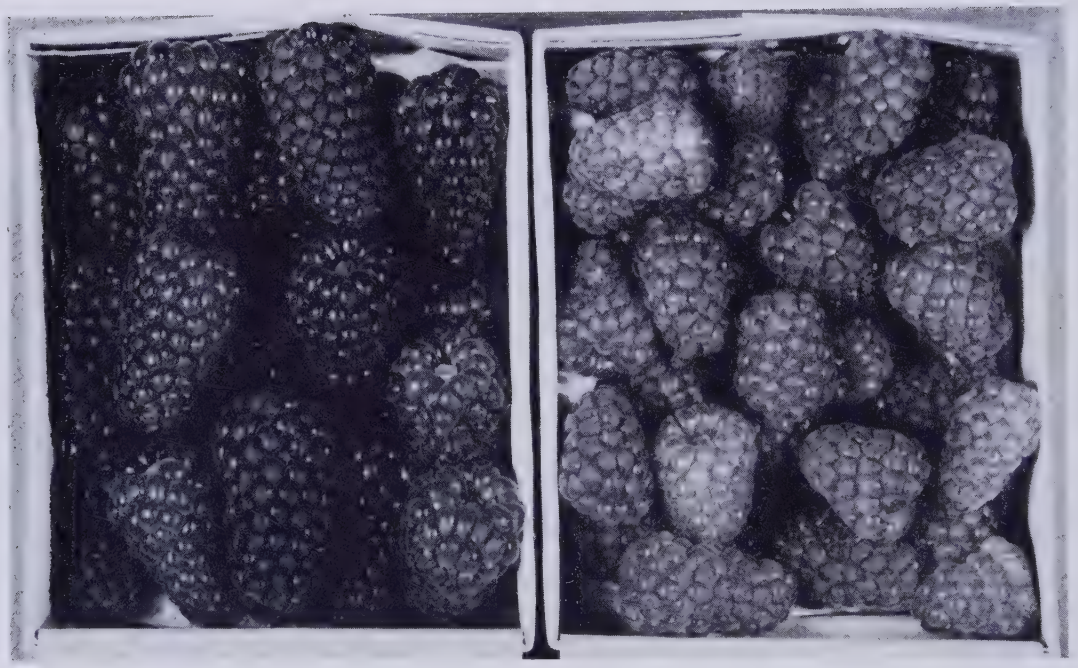


FIG. 4

Typical fruits from clones 463/3, on the left, and 578/1, on the right, showing the greater size and darker fruit colour of the former clone

of the cane of each plant from that of its neighbour so that plants could be recorded individually. These terms were imposed by the intensive type of trial selected for the initial testing of the clones, as being the most economical in labour and land. Although suited to the exigencies of the trial, and capable of demonstrating relative differences in potential yield, the severe pruning involved in this training method may have prevented these exceptionally vigorous plants from reaching their maximum cropping capacity.

As soon as the crop was harvested, the fruiting cane was cut nearly to ground level, removed and burnt, to prevent the spread of cane spot, *Elsinoë veneta*, which may otherwise develop rapidly in early autumn.

Before planting, and during the winter of each subsequent year, dung at 30 tons per acre was ploughed in. Two derris sprays were applied each year in June to control raspberry beetle, *Byturus tomentosus*, nicotine being added to the first to kill aphids and leafhoppers.

Vigour was measured by weighing the young cane removed at the time of the spring training, and the fruiting cane cut out in late summer. A visual estimate, in three categories, of the depth of green colour of the leaves, and records of the extent of frost damage to the fruiting laterals were also made during the summer of 1958. The method of flower insertion on the inflorescence was recorded each year by sample counts of the number of flowers per flower stalk borne in the axil of each leaf. Weight of fruit per plant was recorded at each picking, size samples being taken at intervals throughout the season.

Results

Data on growth, blossoming, and fruiting were examined by analysis of variance, those on the percentage of flowers borne singly being transformed to angles of equal information when much of the data lay outside the limits of 15 to 85%.

Growth.—The vigour and foliage quality of four of the clones was good ; a typical plant of one of them is illustrated in Fig. 1. Clone 578/1 was less vigorous than the others (Table I, Fig. 2), came into leaf later in the season, and bore foliage of a consistently lighter green colour.

TABLE I

VIGOUR OF VIRUS-TESTED LOGANBERRIES

Clone	Origin	Weight of cane	
		1958	1959
		lb	lb
460/2	Eire	9·3	10·8
461/1	Eire	8·8	10·4
463/3	Eire	9·0	10·3
578/1	Eire	6·4	7·4
579/1	New Zealand	8·9	10·8
Sig. diff. (P <0·05)		0·85	0·96

Flower insertion.—Loganberry flowers may be borne singly, in pairs, or in threes in the axil of a bract. In the first blossoming season more of the flowers were borne singly than in the second ; over 75% of the flowers of 578/1 were borne singly in 1957. In all three years 578/1 bore more solitary flowers than the other clones, the relative differences between clones diminishing, however, with the age of the plants (Table II).

Fruiting.—There were differences in yield between clones in all three years. On the whole 460/2 and 463/3, both from Eire, appear to be the most promising (Table III). The maximum crop for these clones—equivalent to about $3\frac{3}{4}$ tons per acre—is a satisfactory yield under the conditions of the experiment. Clone 578/1 was the lowest in yield during the first cropping season, but in 1958 was equal to the New Zealand clone and one of those from Eire. This relative improvement in crop was largely because, being later in leafing out it was less severely damaged by a late winter frost on 11th March 1958, when the air temperature fell to 17° F. Under normal weather conditions in the following year, however, it was once again significantly lower in yield than the other clones.

Two hundred nodes of each clone were examined during the summer for the effects of frost damage, which could then be accurately assessed. Where the primary bud had been killed a secondary lateral shoot was frequently produced from the same node (Fig. 3). Since the secondary laterals were produced later in the season than the primaries, the fruit borne on them was also later in ripening,

TABLE II

FLOWER INSERTION ON THE INFLORESCENCE

Clone	Origin	Peduncles bearing one flower			
		1957		1958	1959
		*	%	%	%
460/2	Eire	53·4	64·4	43·0	52·0
461/1	Eire	58·0	71·9	41·5	48·2
463/3	Eire	56·2	69·0	44·2	47·3
578/1	Eire	67·2	85·0	58·1	56·8
579/1	New Zealand	52·6	63·1	48·8	44·7
Significant difference (P <0·05)		6·41		9·93	8·08

* Data transformed to angles of equal information.

TABLE III

FRUITING OF VIRUS-TESTED LOGANBERRIES

Clone	Origin	Weight of fruit, lb/plant				Relative fruit size No. of berries/lb		
		1957	1958	1959	Total	1957	1958	1959
460/2	Eire	4·7	8·6	11·8	25·1	109	90	94
461/1	Eire	4·6	7·4	10·9	22·9	107	90	92
463/3	Eire	5·0	9·3	11·6	25·9	109	91	92
578/1	Eire	3·0	7·4	8·9	19·3	125	104	106
579/1	New Zealand	4·4	7·4	11·2	23·0	111	88	93
Significant difference (P <0·05)		0·60	0·66	1·08	—	3·9	1·7	2·6

some of it never becoming mature. In addition, the quantity of fruit per lateral, borne on secondary laterals, was less than on normal primaries. About 40% of the buds of clone 578/1 escaped frost damage, whereas only about 25% of the buds of other clones came through unharmed, though 463/3 had fewer nodes completely killed than any of the others except 578/1.

Throughout the period of the trial the fruit size of four of the clones has been exceptionally large, especially in 1958 when samples varied from 88 to 91 fruits/lb. Clone 578/1 consistently bore smaller fruit than the others (Table III, Fig. 4). The fruit size of the best of the new clones compares very favourably with that of the original East Malling selection at, for example, 108/lb in 1939, a good year for fruit size, and the data suggest that the increase in size was not due to heavy pruning.

Disease.—In addition to their freedom from viruses, the plants have been remarkably free from fungus diseases, especially cane spot. The method of training the young cane on a 6-ft wire above the fruiting cane no doubt tended to check the build-up of this disease, since the young cane was not in a position to receive spore-inoculum washed downwards by rain (7). No fungicide was applied from the time of planting until 1959, when copper sprays were used to clear up a small outbreak of cane spot which occurred towards the end of the wet summer of 1958.

Discussion

The cane, leaf, flower and fruit characters of four of the five tested strains closely resembled those described for the Loganberry clone parent selected at East Malling in 1932 (2). The precautions taken to ensure that this plant was similar in morphological characters to the one raised by Judge J. H. Logan, and therefore probably a clonal descendant from it, were described by Beakbane (1). The fifth strain, 578/1, differed from the others in method of flower insertion on the inflorescence, in time of leafing out, and in the lighter colour of its fruit and foliage. In these characters it resembled the Phenomenal Berry, although the morphology of the leaves and cane was entirely typical of Loganberry.

The vigour and yield of the most promising clones were considerably above the present commercial average, and they slightly exceeded that of similar-aged plants of the original East Malling selection

recorded in former trials at the Station. The rapid multiplication of a virus-tested sub-clone (LY. 59) of this original selection has been described by Hobbis and Campbell (5) ; it is on this sub-clone that the recently introduced Special Stock Scheme for loganberries is based. The decision as to whether one of the promising new clones will be offered to the Ministry for inclusion in the Scheme will depend both on the early indications of their potentialities and on any changes that may take place during the next few years in their performance relative to each other and to LY. 59.

Acknowledgements

The authors are indebted to Dr. F. R. Tubbs for initiating this work and for his interest throughout, and to Mr. J. T. Legg for testing the plant material for virus diseases. Thanks are due to Mr. A. Turner (Dublin) and Dr. H. M. Mouat (New Zealand) for providing vigorous strains of loganberries.

Summary

A trial designed to record the relative cropping capacity and other pomological characteristics of five virus-tested clones of loganberry is described. Strain differences occurred in vigour, method of flower insertion on the inflorescence, yield, fruit size, and susceptibility to frost damage. Clones 460/2 and 463/3 are considered to be the most promising.

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EFFECT OF TREE DENSITY IN AN EXPOSED APPLE ORCHARD

By A. P. PRESTON

In an attempt to make use of a more equable climate for fruit growing following the period of late spring radiation frosts from 1935 to 1944, many growers have planted orchards on hilltop sites. This has resulted in fresh problems of climate and growth relationships, one of the most important being exposure to wind. Natural or artificial windbreaks may provide a solution, but some lessening of the wind-flow may be achieved by increasing tree density.

An earlier paper reported the growth and cropping of permanent apple trees on an exposed site planted with and without temporary filler trees on the dwarfing rootstock M.IX (Preston, 1956). This paper presents new data for three 10-acre apple plots with three densities of trees on the same site, also a comparison between the wind-flow on these plots and that over bare land, the relative growth and cropping of the permanent trees, and the performance of filler trees on different rootstocks.

An economic survey of the initial relative cost of establishment of these plots has been published (Butler, 1950), also a paper dealing with the investment aspect (Folley and Yates, 1960).

Site and material

The plantation comprises 150 acres of nearly flat land on an exposed hilltop just below the 500-ft contour on the North Downs in Kent. Most of the land was planted with apples and pears during the period 1945-47, the three experimental areas, each of 10 acres, being planted in 1946. The low density plot contained 17 rows of Cox's Orange Pippin, 5 rows of Worcester Pearmain, and 2 rows each of Sunset and Laxton's Fortune, on the vigorous rootstock M.II and spaced at $25\frac{1}{2}$ ft square, there being no interplant. The medium density plot had, in addition to the permanent trees, one filler tree on the semi-dwarfing rootstock M.VII in the centre of each square of permanent trees. The high density plot had, in addition to the permanent trees, an interplant of three filler trees on the dwarfing rootstock M.IX to every permanent tree, the spacing being $12\frac{3}{4}$ ft square. The same scion varieties were used for the fillers as for the permanent trees.

The arrangement of the experimental plots within the main orchard area is shown in Fig. 1. The orchard was bounded on the east, south and south-west by arable land. In 1947 a hedge of *Thuja*

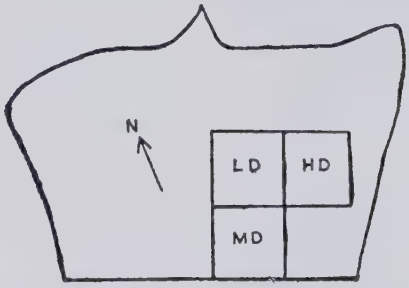

FIG. 1

Plan of the 150-acre orchard showing the experimental low density (LD), medium density (MD), and high density (HD) plots, each of 10 acres.

plicata and *Cupressocyparis leylandii* was planted along the south-west side ; this took several years to equal the apples in height and probably only during the last two seasons have three of the experimental rows in the medium density plot been affected by this wind-break.

Anemometers

A calibrated cup counter anemometer (Meteorological Office, Mk. II) was erected in the centre of each plot, the cups being at the same height as the centre of the head of the permanent trees ; one instrument was erected at the same height in an adjacent grazing field (bare land) on the east side of the orchard. The calibration tests already described (Preston, 1952) showed the anemometers to differ by less than 6%.

Results

Run of the wind*

The percentage decrease in wind-flow on the three plots compared with that on bare land is summarized for the past two seasons in Table I. Trees on the relatively open low density plot decreased the wind-flow considerably, but the biggest decrease was on the medium density plot.

TABLE I

WIND: PERCENTAGE DECREASE COMPARED WITH BARE LAND, FOR DIFFERENT TREE DENSITIES. TREES THIRTEEN YEARS OLD (1958)

Season	Density		
	Low	High	Medium
Blossom period			
1957 (30 days)	21	34	40
1958 (47 days)	22	31	38
Post-blossom period			
1957 (113 days)	28	43	58
1958 (112 days)	28	40	53

The percentage decrease between the three plots during the past three seasons is summarized in Table II. The medium density plot afforded the greatest reduction in wind-flow, with the high density plot next. The data in both tables show the reduction to be greatest during the post-blossom period when the trees were in full leaf and making shoot growth. The blossom period in these tables refers to data from the time the anemometers were set up, just before the onset of blossoming, to 80% petal-fall for Cox.

TABLE II

WIND: PERCENTAGE DECREASE WITH DIFFERENT TREE DENSITIES

Season	Density		
	High < low	Medium < low	Medium < high
Blossom period			
1956 (37 days) ..	19	29	13
1957 (30 days) ..	16	25	10
1958 (47 days) ..	12	20	9
Post-blossom period			
1956 (64 days) ..	20	37	22
1957 (113 days) ..	21	41	25
1958 (112 days) ..	16	34	22

The ratio of wind-flow on the high density to that on the medium density plots was similar, irrespective of wind direction ; for example, during a strong south-westerly wind (Beaufort Force 6) the ratio was 1 : 1·1, and six days later, during a strong north-easterly wind (also Force 6), the ratio was 1 : 1·2 ; thus in the vicinity of the anemometers the exposure of these two plots was similar.

Forty daily anemometer readings in 1957, which included conditions ranging from light winds to fresh gales (Force 8), showed the wind-flow over bare land to range from 64 to 540 miles per day. The daily ratios of the run of the wind between bare land and the medium density plot showed more variation at lower speeds.

Tree size

Tree size was measured by trunk girth in 1958 when the trees were thirteen years old. Two trees were selected at random in each permanent row except the outside guard row on the three plots. Analysis of variance showed trees of Cox's Orange Pippin on the high density plot to be significantly

* Wind-flow past a given point during a period of time.

larger than those on the other two plots (Table III). Earlier data had shown that a soil gradient was unlikely to be responsible for the difference in size between the permanent trees on the adjacent high and low density plots.

TABLE III

MEAN TRUNK GIRTH OF 32 PERMANENT TREES PER PLOT OF COX'S ORANGE PIPPIN ON M.II AT THIRTEEN YEARS

	Density			Significance ratio (P= 0·05)
	Medium	Low	High	
Girth (cm) ..	31·0	31·5	35·4	1·06

The permanent trees on the medium and low density plots did not differ significantly in size and their similarity may be accounted for by the size of the filler trees on M.VII on the medium density plot. These fillers were as large as the permanent trees and their competitive effect seems to have been more serious in restricting the development of the permanent trees than the smaller fillers on M.IX on the high density plot.

Data for the permanent Worcester Pearmain pollinators showed a similar trend, but owing to the small number of trees the figures did not differ significantly.

To allow the passage of tractors and spraying equipment some of the permanent and filler trees in the medium and high density plots had their more spreading branches cut back during the last two years, and for this reason branch spread measurements were not made.

Cropping

The most striking effect of the different tree densities has been that on cropping, and the yields will be considered separately for permanent and filler trees of Cox and the two pollinator varieties Worcester and Sunset (Tables IV and V). The fourth variety, Laxton's Fortune, has been omitted because of its irregular bearing.

Permanent trees

The permanent trees of all three varieties on both the interplanted plots cropped more heavily than did those on the low density plot. The Worcester and Sunset trees cropped more heavily on the high than on the medium density plot, as did the Cox trees during the first ten years. During the past three-year period, however, the Cox trees have cropped more heavily on the medium density plot, but there was some seasonal variation. The mean percentage increase in yield for all three scion varieties, up to the thirteenth year, shows that trees on the high and medium density plots had nearly the same increase in cropping over those on the low density plot (Table IV).

TABLE IV

PERCENTAGE INCREASE IN CROPPING OF PERMANENT TREES ON M.II WITH DIFFERENT TREE DENSITIES

Variety	Density	7-10 years	11-13 years	7-13 years
Cox's Orange Pippin ..	High > low	82	42	59
	Medium > low	61	70	67
	Medium > high	−12	19	5
Worcester Pearmain	High > low	29	47	39
	Medium > low	6	17	12
	High > medium	21	25	24
Sunset	High > low	87	89	88
	Medium > low	33	87	63
	High > medium	40	1	16
Mean for three varieties ..	High > low			57
	Medium > low			53
	High > medium			2

Fig. 2.

(Top) Trees of Cox's Orange Pippin on M.II at 25½ ft. square. Low density plot. (Bottom) High density plot showing additional trees on M.IX spacing 12¾ ft. square.

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Filler trees

The filler trees of all three scion varieties on the dwarfing M.IX have, on a plot basis, cropped more heavily than the larger trees on the semi-dwarfing M.VII, the difference being greatest during the first ten years. During the last three years the difference, though smaller, was still considerable, especially with Cox (Table V). A comparison between the yields of the permanent trees on M.II and the fillers on M.VII in the medium density plot shows that trees of Cox on M.II yielded 24% more fruit than did those on M.VII during the first twelve years, and in the thirteenth year this percentage increased to 65. This is not characteristic of the usual cropping performance of trees on M.VII. Both Hatton (1935) and Preston (1954) reported several field trials in which trees on M.VII were equal in cropping, and in some cases superior, to trees on M.II during the early years.

TABLE V

PERCENTAGE INCREASE IN CROPPING OF FILLER TREES ON M.IX IN HIGH DENSITY PLOT OVER THOSE ON M.VII IN MEDIUM DENSITY PLOT

Variety	7-10 years	11-13 years	7-13 years
Cox's Orange Pippin ..	216	50	119
Worcester Pearmain ..	142	45	84
Sunset	42	10	23

The poor cropping of the filler trees on M.VII resulted in increased vegetative growth and serious competition for the permanent trees, and this factor is probably responsible for the permanent trees being smaller than those on the high density plot (Table III). The heavier cropping of the permanent Cox trees on the medium density plot during the last three years compared with that for the high density plot may have been a direct result of better shelter from the larger fillers on M.VII. A reciprocal effect of the permanent trees sheltering the fillers on M.VII and increasing their crops could be expected and there seems to be no obvious explanation as to why this did not occur.

Discussion

The provision of filler trees between permanent ones on plots in an exposed orchard increased the yield of the permanent trees compared with that from non-interplanted trees, the fillers adding their own productivity to the plot as a whole.

The results show that the choice of a rootstock for filler trees requires careful consideration. Trees on the semi-dwarfing M.VII afforded the greatest reduction in wind-flow but they bore relatively poor crops, and indeed fillers on M.II might have been more profitable in this case. Trees on M.IX did much better, there being little difference in the cropping of the permanent trees of Cox whether the fillers were on M.IX or on M.VII. Furthermore, the smaller trees did not restrict the development of the permanent ones as seems to have been the case with the larger trees on M.VII. A possible reciprocal effect of trees on M.II sheltering the smaller ones on M.IX and thereby increasing their chances of fruit-setting should not be overlooked.

With an interplant of three filler trees on M.IX to every permanent tree on the high density plot a major problem arose within ten years, namely manœuvrability for tractors, gangmowers and spraying equipment. This could be minimized by one of two alternatives. *Firstly*, by planting only one tree on M.IX in the centre of each square of permanent trees. This would reduce the crop per plot from the fillers but it might be compensated to some extent by the trees remaining longer than those in a denser planting. Whether a reduced number of dwarf trees would have the desired effect upon wind-flow and cropping remains to be shown, but encouraging early results from a trial at Luddington Experimental Station have shown that permanent trees on M.II planted at 24 ft square, with one filler tree on M.IX in the centre, cropped more heavily than similarly spaced trees without fillers during the early years of bearing (Hobbis, personal communication). *Secondly*, by using trees on a different semi-dwarfing rootstock, such as No. 3436 now known as M.26, planting one tree in the centre of each square of permanent trees. This new rootstock has made larger trees than those on M.IX yet smaller ones than those on M.VII in recent trials at East Malling (Preston, 1954).

In these trials wind caused serious laceration of the foliage, trees of Cox being severely damaged. The Worcester trees, having tougher and narrower leaves than Cox, were less affected and this may account for the smaller percentage differences in cropping between plots of this variety. The laceration may have been responsible for the difference in size of the permanent trees on the high and low

density plots. A direct result of lessening the wind-flow through the medium and high density plots must have been improved setting and the retention of more fruits than on trees on the low density plot.

A replicated trial is shortly to be planted in Kent to provide an opportunity of determining whether similar differences in wind-flow, growth and cropping occur, on perhaps a reduced scale, on a less exposed site. Such information would establish an important principle in orchard design.

Summary

Three 10-acre apple plots were planted in 1946 as part of a new 150-acre orchard on an exposed hilltop site in Kent. Each plot consisted of permanent trees of Cox's Orange Pippin with Worcester Pearmain, Sunset and Laxton's Fortune as pollinators, all on the vigorous rootstock M.II and planted at 25½ ft square. The first plot consisted of permanent trees only (low density) ; the second had in addition one filler tree on the semi-dwarfing rootstock M.VII in the centre of each square of permanent trees (medium density) ; the third plot had, in addition to the permanent trees, three filler trees on the dwarfing rootstock M.IX to every permanent tree (high density).

To record the wind-flow, calibrated cup counter anemometers were erected in the centre of each plot, and on adjacent bare land. There was a substantial reduction in wind-flow on the relatively open low density plot compared with that for bare land, but the greatest reduction was achieved on the medium density plot.

The permanent trees of Cox on the high density plot were significantly larger than those on the low density plot at thirteen years of age. The permanent trees on the medium and low density plots were similar in size, those on the former plot having had serious competition from the fillers on M.VII which were as large as the permanent trees, The fillers on M.IX in the high density plot were considerably smaller than the permanent trees.

The permanent trees of Cox on the high and medium density plots yielded 59 % and 67 % more fruit respectively than those on the low density plot ; similar results were obtained for the pollinator varieties. The fillers on M.VII did not crop as well as was expected, but those on M.IX did much better, the crops from these trees being additional in each case.

Site, laceration of the foliage, tree spacing, and the choice of rootstock for the filler trees are discussed.

Acknowledgements

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THE GENETICS OF SUCKERING AND TIP ROOTING IN THE RASPBERRY

By R. L. KNIGHT and ELIZABETH KEEP

Red and black raspberries are sharply differentiated by their method of vegetative propagation. The red raspberry (*Rubus idaeus** L.) produces spawn shoots, or suckers, from adventitious buds on the roots, often at some distance from the parent plant, but is unable to root from the tips of its canes ; the American black raspberry (*R. occidentalis* L.), although unable to produce suckers, can root from the tips of any canes that arch over and reach the ground and can also be propagated from leaf-bud cuttings. In a breeding programme involving hybridization between these two species, the inheritance of these contrasting methods of propagation is of obvious importance, since horticultural varieties of raspberry are all vegetatively propagated.

Previous work

Little information has been published on the inheritance of tip rooting and suckering. Colby (2) crossed the black raspberry Quillen with five American varieties of red raspberry. He considered that three of the F_1's showed ratios approximating to 3 : 1, of non-suckering to suckering plants ; the fourth family contained 7% of non-suckering plants, and his fifth cross gave a progeny none of which suckered. Colby's tentative interpretation of these results is discussed in detail later in this paper. Davis (5) working with the *occidentalis* × *idaeus* F_1 variety Royal Purple, found that in crosses with red raspberry both suckering and non-suckering individuals appeared. Of 18 non-suckering red-fruited segregates, one only could be tip layered ; the remaining 17 neither suckered nor tip rooted. Jones and Singleton (8) also, found that backcrosses of ' purple '† raspberries to red included a number of segregates that would neither tip root nor sucker.

Raspberry varieties and selections used as parents

53/9 is a selection from the F_1 of Naples × Malling Enterprise.

75/31 is a selection from the F_1 of Cumberland × 64/53.

78/106 is a selection from a family of Norfolk Giant open pollinated by *R. idaeus*.

Cumberland and Naples are commercial varieties of the American black raspberry, *R. occidentalis*. Lloyd George, Malling Enterprise, and Norfolk Giant are commercial varieties of the European red raspberry, *R. idaeus* var. *vulgatus*.

64/53 is a selection from the cross (Preussen × Baumforth A) × 30/8, Preussen and Baumforth A being at one time commercial red varieties and 30/8 deriving from Lloyd George crossed with the red variety Pyne's Royal.

Inheritance of suckering and tip rooting

F_1 of *R. occidentalis* × *R. idaeus*

Several F_1's of *R. occidentalis* × *R. idaeus* were made by N. H. Grubb by crossing the commercial black raspberry varieties Naples and Cumberland with the red varieties Malling Enterprise and 64/53, respectively. Selected plants from these F_1's were the only material of this type available to the writers ; these showed an almost complete absence of suckering. Grubb (personal communication) found a similar absence of suckering in all such F_1 plants, whereas, of the large number of plants selected by him on fruit characters, none failed to tip root. This ease of propagation of F_1's of *occidentalis* × *idaeus* is well known and such purple cane hybrids are normally propagated commercially by layering the tips of the canes.

First backcross to *R. idaeus*

In 1955, three first backcross families were grown, two of these, Families 139 and 141, deriving from Cumberland, and the other, Family 140, from Naples. In autumn 1955, all canes were layered : this usually comprised two canes per plant. In the following season, four canes per plant, where available, were layered. During this period, also, detailed notes were made on the degree of suckering

* In this paper, *R. idaeus* is considered to include the European raspberry (*R. idaeus* var. *vulgatus*) and the American red raspberry, *R. idaeus* var. *strigosus*, by many authors called *R. strigosus*.

† Purple raspberries are hybrid types resulting from crossing *R. occidentalis* with *R. idaeus*.

in Family 139, the final record being on uprooted plants. The figures given in Tables I and II for suckering and tip rooting segregations represent an assessment based on the work of both seasons. Family 139 contained approximately 63% of triploids (9) and all plants with triploid characteristics have been classified separately in Tables I and II. In classifying plants for their ability to root from the tips of the canes, occasional plants were found in which only a few weakly growing roots were produced. These plants were included in the non-tip-rooting group in all cases. In this connexion, 272 cane tips of a group of 44 red raspberry seedlings and varieties were layered in 1954 ; of these, only six tips showed any root development and this development was comparable with that of the weakly rooting plants described above. In the families classified in Table I, there was considerable variation in the capacity of plants in the ' tip rooting ' class to root, but all were capable of establishing reasonably well-rooted layers.

TABLE I

TIP ROOTING SEGREGATIONS IN FIRST BACKCROSSES

Family no.	Parentage	Observed		Expected		χ^2	P (approx.)
		Tip rooting	Not tip rooting	Tip rooting	Not tip rooting		
				(1 : 1)			
139(2x)	75/31 × Lloyd George	25	24	24·5	24·5	0·02	·9
141	75/31 × 78/106	19	17	18·0	18·0	0·11	·7
142	78/106 × 75/31	4	6	5·0	5·0	0·40	·5
140	53/9 × Lloyd George	25	59	42·0	42·0	13·76	< ·001
				(3 : 1)			
139(3x)	75/31 × Lloyd George	54	20	55·5	18·5	0·16	·7

The figures for Families 139(2x), 141, and 142 are in close agreement with expectation on a 1 : 1 basis, suggesting control of tip rooting by a single dominant or partially dominant gene. The aberrance of the ratio in Family 140 was due to the fact that this family was segregating for tip flowering. Tip flowering in a cane automatically precludes tip rooting in that cane and this explains the deficiency in the tip-rooting class. As layers are normally put down in late August, when potential tip-flowering canes cannot always be recognized, it was not possible to avoid such canes in layering Family 140. The other families had no tip-flowering segregates, so that the ratios in these are reliable.

The expected ratio of 3 : 1 in Family 139(3x) is based on the assumption that a single dominant gene is responsible for tip rooting and that these triploids arose from the fertilization, by haploid red raspberry pollen, of diploid ovules formed by restitution of haploid nuclei after meiosis. The distribution in this family is in close agreement with this hypothesis.

In assessing the phenotype of individuals with regard to their capacity for tip rooting, only plants which had had three or more canes layered were considered to have been tested adequately ; the others have been excluded from Table I and all subsequent tables.

The data on suckering and tip rooting for the diploid plants in Table II show close agreement with a 1 : 1 : 1 : 1 expectation, and the triploid plants agree in their ratio with expectation on a 9 : 3 : 3 : 1 basis. This suggests that tip rooting and suckering are controlled by two independent genes, tip rooting being dominant and suckering recessive. These genes have been given the symbols Tr and sk_1 respectively. On this basis the triploid plants are assumed to segregate as follows :

1 TrTrtr $Sk_1Sk_1sk_1$
2 Trtrtr $Sk_1Sk_1sk_1$
2 TrTrtr $Sk_1sk_1sk_1$
4 Trtrtr $Sk_1sk_1sk_1$
} 9 Tip rooting ; not suckering

1 TrTrtr $sk_1sk_1sk_1$
2 Trtrtr $sk_1sk_1sk_1$
} 3 Tip rooting ; suckering

1 trtrtr $Sk_1Sk_1sk_1$
2 trtrtr $Sk_1sk_1sk_1$
} 3 Not tip rooting ; not suckering

1 trtrtr $sk_1sk_1sk_1$ 1 Not tip rooting ; suckering

TABLE II

SUCKERING AND TIP ROOTING SEGREGATION IN THE FIRST BACKCROSS

Family 139(2x)	Observed			Expected			χ^2	P (approx.)
	Tip rooting	Not tip rooting	Totals	Tip rooting	Not tip rooting	Totals		
					(1 : 1 : 1 : 1)			
Not suckering ..	14	9	23	12·25	12·25	24·50	1·86	·6
Suckering	11	15	26	12·25	12·25	24·50		
Totals	25	24	49	24·50	24·50	49·00		
Family 139(3x)					(9 : 3 : 3 : 1)			
Not suckering ..	41	16	57	41·63	13·88	55·51	0·46	·9
Suckering	13	4	17	13·88	4·63	18·51		
Totals	54	20	74	55·51	18·51	74·02		

F_2 of *R. occidentalis* × *R. idaeus*

Two F_2's of *R. occidentalis* × *R. idaeus*, planted by N. H. Grubb in 1953, were available, Family 104 deriving from Cumberland black raspberry crossed with the red raspberry 64/53, and Family 106 from Cumberland × 30/8.

The plants in Families 104 and 106 were tip layered, both in 1954 and in 1955, and Family 106 was also classified for suckering. The discrepancies between the figures for suckering in this latter family in Tables IV and V are due to plants having died or been discarded before the tip rooting record was complete.

The F_2 data in Tables III-V support the assumption made from the first backcross results, namely that tip rooting and suckering are controlled by two independent genes, that controlling tip rooting being dominant and the other recessive.

TABLE III

TIP ROOTING SEGREGATION IN F_2'S

Family no.	Observed		Expected (3 : 1)		χ^2	P (approx.)
	Tip rooting	Not tip rooting	Tip rooting	Not tip rooting		
104	9	5	10·5	3·5	0·86	·4
106	55	17	54·0	18·0	0·07	·8
Totals ..	64	22	64·5	21·5	0·93	·6

TABLE IV

SUCKERING SEGREGATION IN F_2'S

Family no.	Observed		Expected (3 : 1)		χ^2	P (approx.)
	Not suckering	Suckering	Not suckering	Suckering		
106	71	17	66·0	22·0	1·52	·2

TABLE V

SUCKERING AND TIP ROOTING SEGREGATION IN F_2 (FAMILY 106)

	Observed			Expected (9 : 3 : 3 : 1)			χ^2	P (approx.)
	Tip rooting	Not tip rooting	Totals	Tip rooting	Not Tip rooting	Totals		
Not suckering ..	45	13	58	39·94	13·31	53·25	1·94	·6
Suckering	10	3	13	13·31	4·44	17·75		
Totals	55	16	71	53·25	17·75	71·00		

Discussion

The results presented in this paper have been obtained from crosses between the American black raspberry and English varieties of red raspberry (*R. idaeus* var. *vulgatus*), with the possible exception of those crosses involving 64/53 which carries 25% Baumforth A ' blood ' (it is considered that Baumforth A has some characters suggesting *strigosus* ancestry (10)). The difference between the present results for suckering and those published by Colby (2) are probably due to this difference in the red raspberry parents, all those used by Colby would seem according to Darrow (3) and Hedrick (7) to be of predominantly *strigosus* ' blood '.

Colby's results, to which ' expected ratios ' and χ^2 data have been added for convenience, are tabulated below.

	Observed		Expected		χ^2	P (approx.)
	Not suckering	Suckering	Not suckering	Suckering		
			(3 : 1)			
Quillen × Golden Queen ..	22	7	21·75	7·25	0·01	·9
Quillen × Latham	67	27	70·50	23·50	0·70	·4
			(7 : 1)			
Quillen × Starlight	108	21	112·88	16·13	1·68	·2
			(15 : 1)			
Quillen × June	100	8	101·25	6·75	0·25	·6
Quillen × Ranere	89	0				

Colby argues that the black raspberry Quillen ' is evidently homozygous for tip layering as a method of reproduction since no individuals were found reproducing from suckers in a population of 579, resulting from selfing that variety '. He considers that in the crosses ' with Golden Queen, Latham and Starlight . . . there is the possibility of a simple monohybrid character involved, since approximately 25% of the plants sucker. Quillen-June progeny, however, with only about 7% which sucker, does not fall in this class and suggests a more complex type of inheritance '. Colby's hypothesis of a single gene control in the three families deriving from Golden Queen, Latham, and Starlight is obviously untenable, and he has produced no evidence for his assumption that because Quillen bred true for non-suckering, it must of necessity be homozygous for tip rooting. Quillen is derived from Cumberland crossed with another black variety, Hopkins. Cumberland, the parent of most of the families discussed in the present paper, has been shown to be of TrTr Sk_1Sk_1 genotype. Colby's 3 : 1 ratios in crosses of Quillen with Golden Queen and Latham can only be explained if Quillen is heterozygous for two further genes, Sk_2 and Sk_3, governing non-suckering. That it differs from Cumberland in this respect is further shown by the fact that Anthony (1) found no suckering plants in crosses of Cumberland with June, although Colby obtained such plants in his Quillen × June family. On this assumption, Golden Queen and Latham would be of sk_1sk_1 sk_2sk_2 sk_3sk_3 genotype, it being assumed that sk_2sk_2 in conjunction with sk_3sk_3 enables Sk_1sk_1 plants to sucker. The ratio in the cross of Quillen × Starlight is widely divergent from 3 : 1 ($\chi^2 = 5{\cdot}23$, P = ·02 approximately), but does not differ significantly from 7 : 1, suggesting that Starlight is either of sk_1sk_1 sk_2sk_2 Sk_3sk_3

or sk_1sk_1 Sk_2sk_2 sk_3sk_3 genotype. Colby's cross of Quillen × June, which gave a close approximation to a 15 : 1 ratio of non-suckering to suckering, is explicable on the assumption that June is of sk_1sk_1 Sk_2sk_2 Sk_3sk_3 genotype ; and Ranere, which in its cross with Quillen gave no suckering plants, must be of similar composition to European raspberry, viz. sk_1sk_1 with or without either sk_2 *or* sk_3 but not with both.

Evolutionary significance of sk_2 and sk_3

R. idaeus var. *vulgatus* is basically a European form of the species, the range of which extends into Asia. The American red raspberry, *R. idaeus* var. *strigosus* is, according to Darrow (4), native in the mountains from Georgia to Pennsylvania and in both lowlands and mountains from Maine to the Dakotas, far north in Canada and west to British Columbia. According to him, *R. occidentalis* the American black raspberry, is sympatric with *R. strigosus*, but extends further south and is less common at the northern end of the range. Chance hybridization in the wild between *occidentalis* and *strigosus* is known to be common. Because the two species are sympatric over only part of their range, introgressive hybridization would result in a movement of *occidentalis* genes from the sympatric zone outwards to the pure *strigosus* area. Since ability to sucker is controlled by a recessive gene, such introgressive hybridization would give selective value to any genes capable of reversing the dominance relationship of sk_1. There would be obvious benefit to *strigosus* in building up greater variability and flexibility by the addition of limited amounts of *occidentalis* ' blood ', but the inclusion of the gene Sk_1 with this ' blood ' would place the plant at a selective disadvantage by making it unable to sucker. This has imposed a selection force in favour of reversal of dominance of Sk_1.

Potential value of Tr in a red raspberry background

Thomas (11), working with a range of *Rubus* species, suggested that ability to root from tip layers is correlated with ability to root from leaf-bud cuttings. Garner and Hammond (6) successfully propagated Cumberland from leaf-bud cuttings, whereas repeated attempts to strike similar cuttings of Lloyd George failed. Transfer of the gene controlling tip rooting to a red raspberry, by backcrossing, would presumably enable the red raspberry parent to be propagated from leaf-bud cuttings, and in fact eight second backcross plants, selected by the writers for ability to root from tip layers, were found to root freely from leaf-bud cuttings. This alternative means of propagation would permit rapid multiplication of new varieties and would be especially valuable in the early stages of propagation following eradication of viruses by heat therapy.

Summary

In crosses between *Rubus occidentalis* and *R. idaeus*, tip rooting and suckering are controlled by two independent genes, Tr and sk_1, the former being dominant and the latter recessive. Results of work published by Colby (1936) are interpreted as showing that *R. idaeus* var. *strigosus*, the American red raspberry, can in addition carry the recessive genes sk_2 and sk_3 which together, when homozygous, are assumed to enable Sk_1sk_1 plants to sucker. The transfer of the gene Tr from the black raspberry to the red enables the latter to be propagated by tip layering and by leaf-bud cuttings in addition to the customary method of using spawn shoots.

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WEATHER CONDITIONS DURING 1959

By G. F. TROWELL

East Malling Research Station

The year 1959 will be long remembered for the dry, sunny conditions which persisted throughout the summer and autumn, causing a severe water shortage. The growth and crops of both top and soft fruits would have been far more severely affected had it not been for the reasonably wet March and April. The year ended with a fairly wet November, followed by an extremely wet December. Numerous rainfall, sunshine, and temperature records were broken.

Rainfall during the year amounted to 21·42 in., 5·31 in. below the 35-year average, and 9·10 in. less than in 1958. Only twice during the past twenty-five years has rainfall been below 1959. Although March, April, October, November, and December all had rainfall above average, only December exceeded it by any appreciable amount. An exceptionally dry February (the driest month of the year) broke one of the many records during 1959, as the driest since observations began in August 1914, 0·09 in. of rain falling on six occasions. April on the other hand was the wettest since 1953, 2·02 in. being recorded on 18 days. Of the 1·12 in. of rain which fell during May, on 5 occasions, 0·75 in. fell during a thunderstorm. June and August were the driest since 1949 and 1947 respectively, while September was the driest on record, 0·11 in. falling on only 2 days. The previous driest September was in 1941 when 0·26 in. of rain fell. In the period from May to September inclusive the rainfall of 4·66 in. (on 38 days) was well below the average of 10·34 in.; this was the least rain for this period since 1921, when only 3·55 in. fell. After this long dry spell the rainfall increased with each passing month, and the year ended with the wettest December since 1934 ; this was the wettest month of the year, 4·45 in. falling on 26 days, the highest number in any one month. The heaviest day's rain was 1·16 in. on 26th October. Rain fell on only 153 days throughout the year, compared with 190 last year. The longest wet period of the year was between 6th and 18th April, and the driest period between 2nd and 20th September.

Sunshine remained high throughout most of the year, and totalled 1,900·7 hours making 1959 the sunniest year since 1949 when 1,935·5 hours were recorded ; sunshine hours were 337·7 above the 25-year average, and 540·9 above the 1958 total. Only March, April, and December had sunshine below average. The total sunshine for January was 85·0 hours, the highest figure since records first began. During May to October inclusive sunshine remained exceptionally high, with a total of 1,405·8 hours, 329·8 hours above the average, and more than the total sunshine for 1958 ; this figure was the highest for this period since observations began. Sunshine was recorded every day between 27th May and 9th August, and between 11th August and 20th October. The total sunshine recorded during October was 169·0 hours, breaking yet another record during 1959, the previous sunniest October being in 1921 with 154·1 hours sunshine. The two sunniest days of the year were on 20th June and 6th July when 14·8 hours were recorded. No sunshine was recorded on 57 days during the year, only 4 less than in 1958.

The mean air temperatures were only below the seasonal average during January and February. They were the highest since 1947 in July and August and since 1949 in September. Except during January, mean maximum temperatures were all above average, August and September being the highest since 1933 and 1929 respectively. During October the mean temperature of 53·6° F and the highest reading for the month of 80° F, were the highest since observations began in 1914. The highest screen temperature during 1959 was 90° F, recorded on 5th and 8th July. Mean minimum temperatures were above average during March, April, August, October, and December, with the remainder average, or slightly below. Screen minimum temperatures in March and April were well above average, in fact the lowest screen temperature during March, 31° F, was the highest minimum temperature for this month since records began, and the 32° F recorded during April was the highest since 1943. The lowest screen temperature during 1959 was 20° F, recorded on 17th January.

Spring was slightly earlier than usual, and although Myrobalan B started flowering only 3 days earlier than the average, later varieties such as Cox's Orange Pippin and Edward VII were 12 and 16 days early (Fig. 1).

Ground frosts were slightly fewer than in 1958 (78 compared with 82) the largest number occurring in January. No serious late spring frosts occurred this year. The lowest air frost recorded throughout the blossoming season was 31° F, with only 2 ground frosts in April, the smallest number since April 1937. The first autumn frost was on 23rd October.

The number of cold north-easterly winds occurring in April was well below recent years, but the total of 20 recorded during May was exceptionally high (Fig. 1). Pollination conditions were considered generally good except for the second and third week of April and part of the latter half of May,

Table I

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1959

East Malling

Month	Temperature in Screen (°F)					Number of Ground Frosts	Rainfall (in.)			Sunshine (hours)			Soil Temperatures (°F)			
	Mean maximum	Mean minimum	Highest	Lowest	Mean		Total	Heaviest fall in a day	35 years' average	Total	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
January	42·3	30·0	53	20	36·2	24	2·19	0·33	2·46	85·0	2·74	47	33·6	35·7	38·8	42·6
February	45·6	32·9	63	25	39·3	13	0·09	0·03	1·95	71·1	2·54	68	36·2	37·1	38·5	40·3
March	52·7	37·8	60	31	45·3	11	1·61	0·24	1·57	105·4	3·40	123	43·0	43·0	44·1	43·8
April	57·9	41·8	69	32	49·9	2	2·02	0·45	1·90	148·0	4·93	152	49·3	48·0	48·6	47·2
May	64·1	43·3	80	31	53·7	5	1·12	0·75	1·93	234·2	7·55	200	57·5	54·9	54·9	51·8
June	70·7	48·1	80	36	59·4	0	0·98	0·17	1·63	259·4	8·65	222	65·7	62·1	61·4	56·8
July	75·7	52·2	90	43	64·0	0	1·61	0·70	2·25	290·4	9·37	208	69·7	66·7	66·7	62·0
August	75·0	53·1	86	42	64·1	0	0·84	0·25	2·35	238·8	7·70	194	67·5	65·3	65·9	63·0
September	72·5	49·0	85	35	60·8	0	0·11	0·10	2·18	214·0	7·13	147	62·2	61·9	63·8	62·6
October	64·4	42·8	80	32	53·6	2	2·87	1·16	2·85	169·0	5·50	105	51·4	52·8	56·5	58·2
November	51·7	36·4	60	23	44·1	11	3·53	0·93	3·18	59·8	2·00	55	41·6	43·3	46·8	50·6
December	48·6	37·3	54	29	43·0	10	4·45	0·57	2·48	25·6	0·83	42	40·4	41·6	43·9	46·9
Totals						78	21·42		26·73	1,900·7		1,563				

Sub-Station, Newlands Farm, Throwley

January	41·1	30·0	51	20	35·6	25	2·55	0·48		96·5	3·11		35·1	36·2	40·2	44·5
February	43·8	33·1	60	25	38·5	16	0·03	0·02		81·1	2·90		36·7	37·2	38·7	41·9
March	50·7	39·0	57	29	44·9	7	2·22	0·38		101·1	3·26		43·0	43·1	44·0	43·9
April	55·7	41·4	66	33	48·6	4	2·71	0·66		142·3	4·74		48·5	48·0	48·6	46·8
May	60·9	44·0	76	34	52·5	2	0·86	0·28		238·7	7·70		54·8	53·8	53·8	50·6
June	68·4	48·7	78	40	58·6	0	1·21	0·33		284·5	9·48		63·3	61·0	59·7	54·8
July	72·9	54·1	86	44	63·5	0	1·66	0·52		300·1	9·68		67·4	65·4	64·6	59·5
August	72·6	54·2	82	44	63·4	0	1·10	0·43		248·4	8·01		65·4	64·3	64·4	60·9
September	70·0	51·6	83	43	60·8	0	0·18	0·18		209·9	7·00		60·0	60·1	61·3	60·1
October	62·0	46·3	77	34	54·2	2	3·40	1·26		177·0	5·71		51·9	52·9	56·1	57·4
November	50·1	40·3	57	29	45·2	10	4·72	1·25		67·1	2·24		42·3	43·3	47·9	51·6
December	46·6	37·4	52	31	42·0	10	6·84	0·77		27·7	0·89		40·7	41·0	44·4	47·6
Totals						76	27·48			1,974·4						

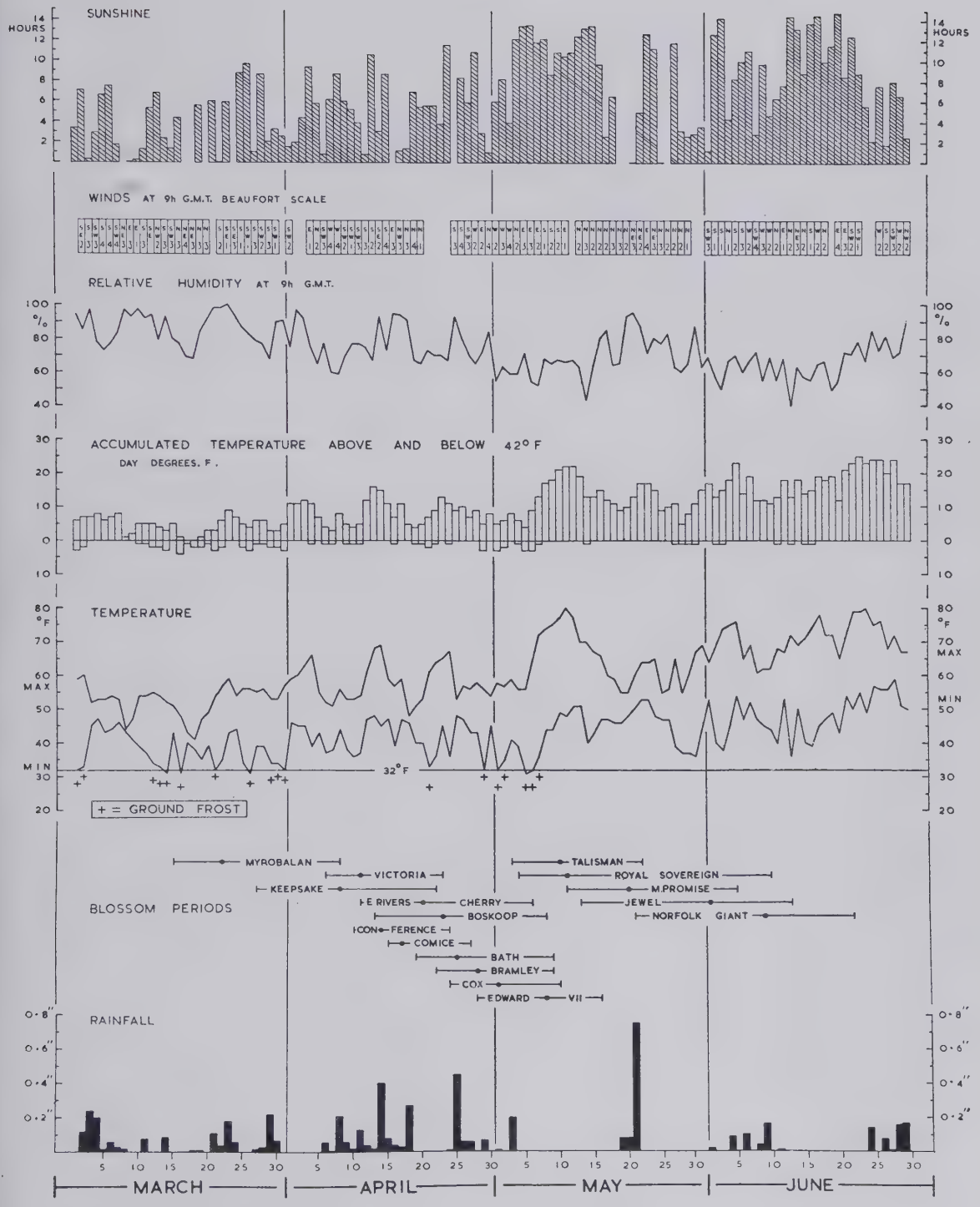

FIG. 1

Diagram showing the weather recorded during the blossoming season at East Malling Research Station in 1959

when conditions were poor. Gale force winds of 40 m.p.h. were recorded only twice, on 22nd January and 27th October. Strong winds of ' Force 6 ' and over occurred 26 times with the largest number in January. Winds from a south-westerly direction were recorded on 104 days, compared with 127 in 1958, and 122 in 1957.

There were 15 thunderstorms over or in the neighbourhood of the Station, but only a few were violent or severe. One on the night of 21st May and again early morning of 22nd, brought heavy rain and hail, with one isolated gust of 42 m.p.h. ; approximately 0·09 in. of hail was collected in the Station hail gauge, from the 0·75 in. of rain recorded. Distant thunder was heard 21 times during the year. Hail was recorded 6 times, all during the first half of the year.

The total amount of snow and sleet recorded over the past year was almost nil, occurring only 4 times, all during January. The ground was snow covered 3 times, to a depth of $\frac{3}{4}$ in. No snow fell during the second half of the year.

Fog was experienced on 46 occasions, the foggiest month being February.

Ground conditions were good for spring planting, the ground being frozen only twice during the second half of February, and not at all during March. Extremely dry ground conditions, with some soil cracking on a number of occasions, were experienced during much of summer and autumn ; in fact from 1st May to 10th October, moist or wet ground was recorded only 30 times, and only once during September. Conditions were good for early stock lifting and planting during October and November.

Newlands Farm, Throwley

Rainfall at this sub-station totalled 27·48 in., and, although 6·06 in. higher than at East Malling, its distribution was the same. February was the driest month with 0·03 in., falling on only 2 days. The heaviest day's rainfall was on the same day as East Malling, 1·26 in. on 26th October. December was the wettest month with 6·84 in. on 25 days. Rain fell on 136 days during the year, 17 less than at East Malling.

The total sunshine was as usual higher than at East Malling, by 73·7 hours. The sunniest day of the year was on 7th July when 15·3 hours sunshine were measured.

Mean air and maximum temperatures at this sub-station were generally below those at East Malling, while the mean minimum temperatures were above. The highest screen temperature recorded was 86° F, on 5th and 8th July, and the lowest 20° F, on 14th January. The total number of ground frosts was slightly fewer than at East Malling, the largest number being recorded in January.

Only one air frost was experienced in March. The first autumn frost was on 23rd October.

Thunderstorms and distant thunder were recorded 16 times.

Snow and sleet fell 8 times during January, March, April, and November. Hail was experienced 7 times.

Gale force winds were recorded on 15 occasions.

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STATISTICS AND RECORDS

THE ASSESSMENT OF WOOD GROWTH ON BLACK CURRANT BUSHES

By G. H. FREEMAN and J. A. THOMPSON

The assessment of the amount of one-year-old wood on black currant bushes is useful, since this is where most of the crop is carried. Thus, this measurement gives an indication of fruiting potential, and it also provides information on vegetative vigour. In this way, a means is afforded of determining the mechanism of an effect in a way which is impossible solely from a record of crop. Previous studies of wood growth of black currants have not achieved results commensurate with the considerable effort expended. This has been due to the labour of taking the actual measurements and the difficulty of ensuring that all shoots have been recorded.

Methods for ensuring complete enumeration

In order to measure black currants it is necessary to enumerate the shoots, and this is most easily done by concentrating on the base of the bush. With many bushes, particularly young ones, branches and new shoots appear in a more or less circular pattern, possibly with outliers, and all that is necessary is to note the starting point on a bush and to work round it. Older bushes, however, often have a less defined pattern ; the branches can then be divided into groups with string and a systematic approach adopted within each group separately. The exact system is unimportant, provided that every shoot is included. When enumerating shoots along a main branch it is best always to work in the same direction, according to personal preference. The method has been tried on young bushes, where it is easy, and also on older bushes, where it is not so difficult as might be supposed.

Measurement of wood growth

It is difficult to measure more accurately than to the nearest decimetre and this is quite sufficient for practical purposes. Further, shoots less than fifteen centimetres can usually be ignored, as these tend to be laterals contributing little to fruit production ; hence, it is not usual to record any measurement less than two decimetres.

It is often impracticable, for reasons of time or labour, to measure all the shoots on every bush in a plot. The usual practice has been to measure every shoot on a sample number of bushes, but better results should be obtained, for the same amount of measurement, by spreading the sample over all the bushes. If this is to be done, an appropriate sampling system is needed. Jolly and Holland (1), faced with a similar problem on apple trees, recommend two methods, Systematic Shoot Sampling and Random Branch Sampling. The latter is not suitable for black currants, but an adaptation of the former has been found satisfactory. In this method, every nth shoot is measured, following the system of enumeration outlined above. For black currants a sample of at least ten shoots per bush should be taken, and this may require a value of n between about three and twelve. If, as Jolly and Holland recommend, the first shoot is always measured, there will be a considerable overestimate with the lower values of n ; thus, a random starting point seems advisable. With two recorders working together, as is customary, the one doing the measuring should decide which main branch to start on and the other should say which number shoot shall be taken as the starting point. This leads to the elimination of any personal bias, such as an attempt, possibly unconscious, to ' even up ' the results with respect to previous bushes in the same plot.

Accuracy of sampling

To assess the accuracy of the sampling method data were examined from two trials, each containing the varieties Goliath, Baldwin, Wellington XXX and Westwick Choice. Six years' records were considered, three from each trial ; thus, a wide range of ages of bush was covered. Four bushes per plot had been recorded, before pruning, out of a total of ten or twelve, and samples were drawn from these records by taking a random starting point and then every nth shoot, as described above. In each year the four varieties were considered separately, so that there were 24 sets of data ; half of these were based on 32 bushes, the rest on 40.

As a supplement to this main set of data, measurements were taken by the authors on pruned bushes in two plantations, one where the bushes were 4 years old, the other where they were 8 years old. The younger area had separate blocks of each of the varieties Mendip Cross, Wellington XXX and Westwick Choice, and the other consisted of three replicates of eleven varieties in randomized blocks of single-bush plots. Complete measurements were taken for ten bushes of each of the three varieties in the younger plantation and for all of the bushes in the older, and these records were then sampled. To get samples of the correct size, one shoot in three was selected for the younger bushes and one in four for the older.

The results obtained from the analysis of these data are shown in Tables I and II. The correlation coefficients and the parameters of the regression equations were obtained ignoring treatment effects for the main set of data and effects of varieties in the 11-variety trial, since any sampling method must apply to all types of bush if it is to be acceptable. The increase in variability due to sampling, however, is expressed on the basis of the variation between bushes within plots, as it is this variation that should be reduced by spreading the sample over more bushes.

The lowest of the correlation coefficients is 0·726, that is to say, more than half of the variation in the estimated value (y) is accounted for by variation in the true value (x).

Table I

Results obtained from main set of data

Goliath						Baldwin					
Year	Sample	r	p	b	a	Year	Sample	r	p	b	a
1946	1 in 5	0·889	51·4	1·019	43	1946	1 in 3	0·918	83·5	1·032	−81
1947	1 in 6	0·847	39·2	0·984	20	1947	1 in 6	0·885	41·7	1·095	−82
1948	1 in 7	0·858	68·7	0·946	87	1948	1 in 7	0·839	97·8	1·039	11
1949	1 in 10	0·843	24·4	1·021	20	1949	1 in 8	0·849	170·1	1·184	−440
1950	1 in 6	0·866	19·8	1·005	−5	1950	1 in 6	0·893	96·7	1·229	−408
1951	1 in 8	0·811	28·4	0·932	178	1951	1 in 10	0·726	108·0	0·982	69
Wellington XXX						**Westwick Choice**					
Year	Sample	r	p	b	a	Year	Sample	r	p	b	a
1946	1 in 8	0·773	58·5	0·964	26	1946	1 in 5	0·942	13·9	0·969	64
1947	1 in 10	0·854	96·6	1·224	−516	1947	1 in 8	0·775	95·8	0·878	133
1948	1 in 10	0·735	49·5	0·861	501	1948	1 in 9	0·846	55·2	0·926	221
1949	1 in 10	0·745	38·3	0·984	155	1949	1 in 10	0·752	0	0·767	773
1950	1 in 10	0·884	51·8	1·077	−168	1950	1 in 7	0·893	17·8	0·968	135
1951	1 in 12	0·750	122·3	1·050	−226	1951	1 in 10	0·863	141·6	1·270	−833

r is the correlation coefficient between x, actual wood growth in cm, and y, estimated wood growth in cm, ignoring treatments.
p is the percentage increase in variability between bushes within plots due to sampling.
b and a are obtained from the best linear regression of y on x, $y = a + bx$, ignoring treatments.

Table II

Results obtained from supplementary set of data

Variety	Sample	r	p	b	a
Mendip Cross	1 in 3	0·910	3·8	0·927	18·8
Wellington XXX	1 in 3	0·761	0	0·597	78·2
Westwick Choice	1 in 3	0·902	59·2	1·138	−18·7
11 varieties	1 in 4	0·952	29·5	1·009	6·0

r is the correlation coefficient between x, actual wood growth in dm, and y, estimated wood growth in dm (ignoring varieties for the 11-variety trial).
p is the percentage increase in variability between bushes due to sampling (eliminating varieties for the 11-variety trial).
b and a are obtained from the best linear regression of y on x, $y = a + bx$ (ignoring varieties for the 11-variety trial).

Of more importance, however, is the percentage increase in variability due to sampling, since the variance of any result obtained from sampling may be assumed to be made up of independent components of variance due to the inherent variability of the material and to sampling error. Thus, the component due to sampling varied between virtually zero and 170% of the inherent variability, and the size of this component did not appear to be in any way related to the fraction of the whole bush represented by the sample. Even on the basis of the worst of these results, greater accuracy would have been obtained by taking a sample from all the bushes than a complete record from only some, and the total amount of measurement would have been less.

For each set of data separately a test was carried out to find whether the regression of y on x differed from the expected value $y = x$. In only one of the main sets of data was this difference significant at even the 1 in 10 level, while the worst of the supplementary set was Wellington XXX, where the level of significance was 1 in 40. These results, from 28 sets of data, agree closely with expectation ; the poor value for Wellington XXX points to the inadequacy of estimates based on as few as ten bushes. The values of b and a obtained from the best linear regression of y on x, $y = a + bx$, are given in the Tables, but their standard errors are not given as these would be dependent on each other.

Conclusions

Ideally, the assessment of wood growth should precede pruning if the purpose is to determine vigour, and should follow it to indicate fruiting potential. However, to save labour, lengths need only be measured *after* pruning. To obtain total extension growth the length of prunings could be estimated from the total weight of prunings and the weight of a sample length, and then added to the length remaining after pruning.

The results of the last section show that sampling, both before and after pruning, gives accurate results. The complete measurement of a large, old bush is certainly laborious and may not be feasible in regions where bushes grow more vigorously than they do in South-East England. Nevertheless, the shoots on such bushes can probably still be completely enumerated and a sample measured.

The method of systematic sampling with a random starting point is sufficiently accurate for most practical purposes. However, as the same sampling fraction might not be appropriate for different varieties, comparisons of varieties should not be based on results obtained from sampling. Further, the extra variability induced by sampling is such as to preclude its use on single-bush plots. When there are more bushes to a plot, sampling from all bushes gives more accurate results than complete measurement of only some, and, moreover, fewer shoots need be recorded. The closeness of the best regression line to $y = x$ suggests that estimates obtained by sampling can be used not merely to compare different bushes but also to give actual values of wood growth. Thus the total wood growth on a bush can be obtained by multiplying the length of wood in the sample by the value of n for the bush. Some extra labour is involved in handling every bush, but the reduction in the total amount of measurement should more than offset this. Hence, for most practical purposes, sampling methods should be used, and as few as ten shoots per bush will give sufficiently accurate results.

Summary

A method of measuring wood growth on black currant bushes is described. Shoots are measured to the nearest decimetre, and, for most purposes, a sample of about ten shoots per bush is sufficient. The sampling method consists of taking every nth shoot, with a random starting point. More accurate results are obtained with less labour by measuring a sample on all bushes in a plot than the whole of only some, but sampling is not recommended for single-bush plots or comparisons of different varieties.

Reference

(1) Jolly, G. M., and Holland, D. A. (1958). Sampling methods for the measurement of extension growth of apple trees. *Rep. E. Malling Res. Sta. for 1957*, 87-90.

PLANT PHYSIOLOGY

SEASONAL CHANGES IN THE CARBOHYDRATE RESOURCES OF SOME SIX-YEAR-OLD APPLE TREES

By C. A. PRIESTLEY

' Reserves ' may be defined as materials produced in excess of current requirements and which may later be used in support of metabolism and growth. The initial spring growth of deciduous fruit trees must obviously be wholly dependent upon food reserves stored in the trees from the previous season—until such time as the new leaves can carry out active photosynthesis. Many attempts have been made to estimate the quantities of reserve material present in fruit trees throughout the year, but so far these have provided no complete definition of the nature or function of carbohydrate reserves. The lack of progress in this field during the past fifty years may in part be due to a failure, firstly, to define which of the component carbohydrates present in the living tissue may be accumulated for later use, and secondly, adequately to relate analytical data to the pattern of behaviour and growth of the trees themselves.

The results recorded in this paper, although preliminary, serve to illustrate methods by which it is hoped to define the ' reserve ' fractions of the extractable carbohydrates and to show how seasonal changes may be related to the periods of growth of the tree.

Materials and methods

The samples were obtained with the assistance of members of the Plant Analysis Section from trees which they were ' harvesting ' for analyses of mineral elements (see Mason and Whitfield, in press). The trees used were 6-year-old M.IX growing on the rootstocks M.IX and M.XVI. Ninety-six trees were used in the investigation, being ' harvested ' monthly in random groups of four trees on each rootstock. Bark and wood were taken from seven regions of the tree, and representative samples for carbohydrate analysis obtained from the following numbers of shoots or roots :

Current year's extension shoots One-year-old extension shoots Medium-sized roots	5 units per tree
Main branches Old roots	3 units per tree
Scion trunk Stock trunk	1 unit per tree

Separate bark and wood samples from each region were obtained from trees on both rootstocks so that 28 sets of material were collected for analysis at each harvest.

Bark was obtained as rings about $\frac{1}{8}$ in. wide around each unit sampled, and the bulked samples from the four trees of each set were macerated after being preserved by dropping into boiling 80% methanol. Wood was then obtained as sawdust from a transverse saw cut made through the gap left by the removal of the bark sample ; this sawdust also was preserved by covering it with boiling 80% methanol. The method of preservation was chosen since no loss of total sugars from samples stored in methanol had been found previously.

Large daily fluctuations in carbohydrate content are known to occur in leaves, and since this work was mainly concerned with ' reserves ', no carbohydrate analyses of leaf material were carried out.

Analytical procedure

The preserved macerated tissues (0·5-1 g dry wt) were extracted in a micro-Soxhlet apparatus by a procedure which provided four fractions of carbohydrate cell constituents. These were defined primarily by the method of extraction, and comprised :

(i) Glucoside (phloridzin)
(ii) Soluble sugars
(iii) Starch
(iv) Hemicellulose(s)

Extractions initially with 70-75% methanol for 7-8 hours yielded alcoholic solutions containing phloridzin (i) and soluble sugars (ii). After such extractions the alcohol was made up to volume (50 ml) and four aliquots (0·25 ml each) streaked progressively on to Whatman 3MM chromatography paper. Development with 2% acetic acid yielded two bands containing respectively phloridzin (R_F *c.* 0·32) and soluble sugars (just behind the solvent front).

Starch (iii) was then extracted from the tissue residue by a procedure modified from that of Niemann, Roberts and Link (1935) and Hanes (1936). The residues were retained in the Soxhlet thimbles and covered with cold 1% HCl in 96% aqueous methanol until liquid siphoned into the distillation flasks. These were heated for one hour, after which the acidified methanol was replaced by 96% aqueous methanol and heated for a further hour. The methanol was then removed and the extractor thimbles and their contents dried. This procedure resulted in ' solubilization ' of starch which was extracted for 7-8 hours with water in the Soxhlet apparatus and then made up to volume.

Finally, residues were dried and removed from the extraction thimbles to the flasks of the Soxhlet apparatus where they were boiled for one hour under reflux with N H_2SO_4. This final stage yielded a carbohydrate believed to correspond closely to hemicellulose (iv) as extracted by other workers (Gerhardt, 1929). The extracts were filtered and made up to volume, while the insoluble residues were washed and dried before being weighed to provide a basis on which differences in carbohydrate content could be expressed.

Aliquots from the fractions corresponding to phloridzin, soluble sugars, starch and hemicellulose were estimated (in terms of sugar) by the method of Bradfield and Flood (unpublished) which is based on that of Rappaport, Reifer and Weinmann (1937). By this method, all carbohydrates in solution are estimated by determination of the sodium metaperiodate required for their oxidation.

Expression of analytical results

The weight of tissue residue after extraction was chosen as a basis for comparison of results because this residue is thought to be representative of structural cell material within which carbohydrate resources (and related compounds) are stored and also utilized. It had been hoped that it would be possible to use figures for total (Kjeldahl) nitrogen as an estimate of living material (protein) and as a basis for comparison of results. However, marked seasonal changes occurred in the total nitrogen which seemed unrelated to the distribution of living tissues, and consequently results were expressed only in terms of the residue left after extraction. This residue dry weight is not subject to the same criticism as total dry weight, for changes in one component metabolite do not automatically affect other components inversely.

Tree to tree variation in size was considerable in this experiment, particularly among the M.IX/IX trees, but the use of residue dry weight as a basis enabled comparisons to be made between corresponding regions of M.IX/IX and M.IX/XVI trees.

Results

The results of this series of analyses demonstrate the behaviour of whole plants of one scion variety (M.IX) on two different rootstocks (M.IX and M.XVI). Each of the four carbohydrate components (phloridzin, sugars, starch, and hemicelluloses) was involved in seasonal changes and these changes can be related to the phases of growth of the trees.

Dry weight changes

The dry weights of the various regions of the trees were obtained as mean values for the four trees of each ' harvest '. The weights for the M.IX/XVI trees were taken from direct measurements, but originally the different below-ground regions of the M.IX/IX trees were weighed together and the weights of the M.IX/IX scion trunks were recorded with the branches. Data from a comparable experiment were used to calculate the distribution of dry weight in the same regions that were sampled for carbohydrate analyses.

The maximum leaf area was attained between the end of March and the end of June, whereas the period of most rapid shoot extension was from the middle of June, coming to an end about a fortnight earlier in July in the M.IX/IX than the M.IX/XVI trees.

Seasonal changes in total carbohydrates

The values for the four component fractions of the extractable carbohydrate, expressed in terms of sugar equivalent, were added together and the results for the totals in the various regions are shown in Fig. 1 (left). Although there was apparently some redistribution of the total extractable carbohydrate at about the time of bud-break, the results illustrate that a relatively rapid depletion of reserves as the first leaves expanded was quickly succeeded by replenishment before shoot extension

became active. An early summer maximum (as described by other workers) was thus established by the end of June and was followed by a second minimum during the period of most active extension growth. Differences between the carbohydrate content (as g 100 g residue) of the M.IX shoot system on the two rootstocks prior to shoot extension were insignificant, but it is noteworthy that during extension growth the level of resources in the M.IX/XVI trees was consistently lower than in the M.IX/IX trees. This is interpreted as being due to the effect of the greater amount of extension and secondary growth made by the M.IX XVI trees. The total growth made by the M.IX XVI trees was about three or four times that made by the M.IX/IX trees, despite the lower content of total carbohydrate resources in the M.IX/XVI trees. Clearly the overall level of carbohydrate was not limiting growth, although the rate of growth influenced the level of resources. The consistent differences between the M.IX scions on the two rootstocks, which were apparent during the season of active extension growth, tended to disappear after leaf-fall, when a decline in the total carbohydrate occurred.

An analysis of variance was carried out on the data for the total extractable carbohydrate from bark and from wood throughout the tree. Such an analysis does not completely account for seasonal trends, but the results were sufficient to illustrate that the effects due to rootstock, region of tree, and (in the bark) sampling time were all highly significant. The variance due to time in the wood analyses was not significant, but it was evident from monthly average figures for the whole tree that, although the actual figures were less, the wood showed the same general trends as the bark.

Component carbohydrates

Analyses of variance were carried out on the data for the carbohydrate fractions extracted from bark and wood.

Phloridzin.—The variability in the case of phloridzin was relatively large, but significant differences due to time of year were detectable in the wood and scion bark regions. However, phloridzin did not seem to follow closely the variation in other carbohydrate components in relation to the phases of growth. There was no detectable difference between the time course of changes in phloridzin content in the bark on the two different rootstocks, or in the different regions of the tree (as determined by the first order interactions ' Time × Rootstock ' and ' Time × Region ').

Sugars and Starch.—The amounts of sugar and starch are best considered together since it was evident that both classes of compound undergo significant seasonal fluctuations. These reflect the depletion that occurs at times of rapid growth and the accumulation that occurs when photosynthesis exceeds the demand. Sugar and starch are stored and utilized at similar times although possibly at different rates, but it was apparent also that some seasonal interconversion of sugar and starch occurred, particularly in the bark. Thus, at the beginning of the year before growth commenced, the amounts of starch were observed to increase while amounts of sugar decreased, and conversely at the close of the year when the trees became ' dormant ', the amount of soluble sugars increased while starch decreased. Analyses of variance on the data for soluble sugars and starch throughout the tree established that there were significant effects due to sampling time, rootstock, and region of tree and the interaction of these factors. Analysis of data for the scion region alone showed significant differences in sugar content above the two rootstocks, but on the other hand the starch content of the M.IX scions showed no significant variation due to rootstock. This is demonstrated in Fig. 1 (right), which also illustrates the distinction below ground between the two rootstocks. The similarity in scion starch content existed despite the fact that the M.IX IX trees were approximately one-third the size of the M.IX/XVI trees and made a correspondingly smaller amount of new growth during the season.

Hemicellulose(s).—The hemicellulose content of bark and wood above and below ground showed significant variations due to time of year, and rootstock and region sampled. The fluctuations which occurred coincided with those in other extractable carbohydrates and there seems little doubt that, in the apple, hemicellulose (as defined by the method of extraction) plays a part as a reserve material which may be utilized at times of rapid growth. The hemicellulose fraction is not a homogeneous compound and possibly a proportion of it can function as reserve carbohydrate, although the remainder is largely structural in character.

The claims of some other workers (e.g. Winkler and Williams, 1938) that the apparent utilization of hemicellulose is due to the expression of results on a total dry weight basis cannot be upheld in the present case. In fact the evidence suggests that each of the four types of carbohydrate can function as a ' reserve ' at some time of the year.

Distribution of carbohydrate resources within the tree

There is a gradient of increasing carbohydrate content per unit residue dry weight from the shoots to the roots of the apple tree, so an average figure based on unit residue dry weight for regions

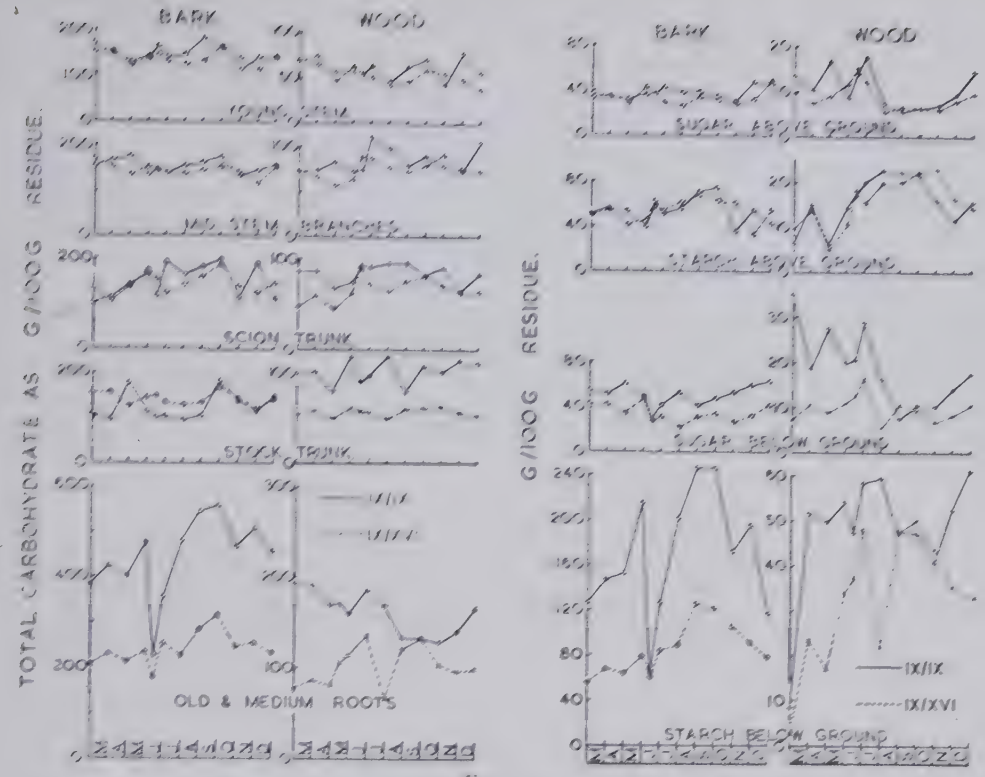

FIG. 1

Seasonal distribution of carbohydrates within 6-year-old apple trees of M.IX/IX and M.IX/XVI
Left: Total extractable carbohydrates in different regions of the tree.
Right: Starch and sugar as average figures for the stock and scion regions.

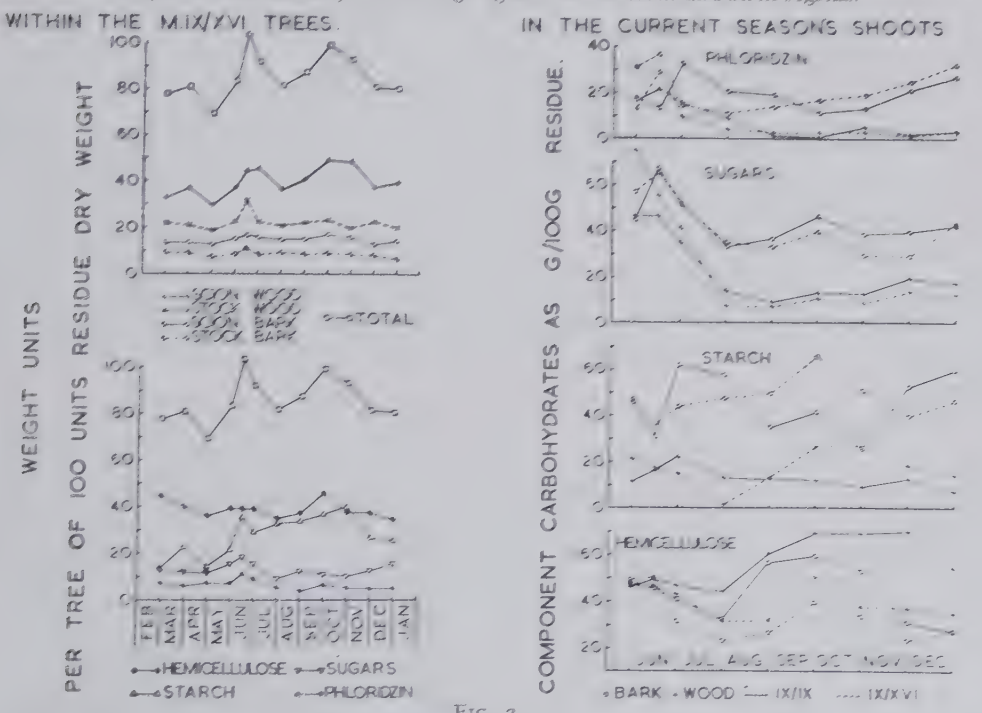

FIG. 2

Distribution of fractions of the extractable carbohydrates

Left upper: Proportions of total extractable carbohydrate in bark and wood of M.IX/XVI stock and scion.
Left lower: Seasonal distribution of component carbohydrates within the whole tree of M.IX/XVI.
Right: Seasonal distribution of component carbohydrates in the current season's shoots of M.IX/IX and M.IX/XVI.

occupying different volumes does not give a true picture of the distribution of resources. This may be obtained by taking account of the distribution of dry weight within the different regions of the tree. Dry weight measurements were based on mean values for the several regions of four trees at each harvest, but the variation of individual tree size was too great to present a complete annual curve of growth. However, the distribution of supposedly inert residual dry matter within the tree remained virtually constant and independent of tree size, so it was possible to express the carbohydrate content of bark and wood, above and below ground, as percentages of the residue dry weight of the tree (Fig. 2 ; left). This data showed no significant interaction at the 5% level between time and region of the tree although the main effects were highly significant, suggesting that the distribution of carbohydrate resources remains constant even though the total amount in the tree fluctuates. This suggests that the apple tree has no clearly defined storage organ.

The actual dry weights of the different regions of the M.IX/XVI trees and the estimated figures for the corresponding regions of the M.IX/IX trees were used for calculating the distribution of the total dry weight and of the carbohydrate as percentages of their respective totals in the tree. Mean values of the figures for all twelve sampling times are shown in Table I. In spite of some approxi-

TABLE I

COMPONENTS AS PERCENTAGE OF TOTAL IN TREE

		Total dry weight		Extractable carbohydrate	
		M.IX/XVI	M.IX/IX	M.IX/XVI	M.IX/IX
Above ground	Bark ..	14·1	13·8	17·3	16·0
	Wood ..	51·9	59·2	46·3	52·1
Below ground	Bark ..	7·0	6·9	10·2	9·8
	Wood ..	27·0	20·1	26·2	22·1

mations in the calculation of the M.IX/IX figures the distribution of resources above and below ground is strikingly similar for M.IX trees on both rootstocks. The M.IX rootstock system is relatively smaller than that of M.XVI, but this seems to be offset by a greater capacity for storing carbohydrates. There are relatively fewer non-living cells in the root of M.IX than in more invigorating rootstocks (Beakbane, 1941) suggesting that the amounts of carbohydrate per unit of residue dry weight may be related to the proportion of living to non-living cells in the tissues. This is evidenced also by the differences between bark and wood, the higher carbohydrate content per unit residue of bark corresponding to a higher proportion of living cells. Moreover, the maintenance of a similar distribution of carbohydrate resources, which was observed within the trees throughout the year, implies that there is an equilibrium between the different regions so that the amount of a metabolite in one part is related to that in any other. This might be expected *a priori* for the M.IX/IX trees, since there is no reason to suppose that particular carbohydrates would be of different significance to the different cells of the same genotype, but it is interesting to find that an equilibrium is maintained between the living cells of M.IX scions and M.XVI rootstocks. The result further implies that carbohydrate storage in an apple tree may take place without the presence of a discrete or transitory storage organ.

Current season's extension growth

The results for the current season's extension growth have been recorded in Fig. 2 (right) separately from the remainder, since they demonstrate differences between growing and mature regions of the tree. It has already been pointed out that the carbohydrate content of the mature M.IX scion shoot system was similar at the beginning and end of the growing season whether on M.IX or M.XVI rootstocks. By the end of the growing season the carbohydrate level of the new shoot was closely similar to that of the previous year's shoot at the beginning of the current season.

The sugars and glucoside fractions showed a close similarity between shoots on both rootstocks, starting at a high level in the new growth and declining rapidly during shoot extension, showing only a slight increase toward the end of the season. Such a marked decline during the period of maximum extension growth had not been observed in the older regions of the tree and was presumably due to the maturation of the shoot—during which a proportion of the initially living cells would be converted to structural elements such as fibres and xylem. This would give rise to an increase in the residue dry weight (against which the carbohydrate content was assessed) and an increase in the proportion of ' non-living ' cells unconcerned with carbohydrate metabolism. Differences which

did occur between the sugar contents of the M.IX/IX and M.IX/XVI new shoots were consistent with the previous observation that a lower level of sugar was consequent upon a higher rate of growth, the lower sugar contents being observed in the M.IX/XVI shoots.

The starch contents of the new shoots showed irregular fluctuations during the growing season in both sets of trees, but the level was similar at the beginning and end of the season. This may be reconciled with the observed decline in sugar content on the assumption that the dilution effect of the maturing of the shoot was compensated for by an increasing ability for starch synthesis and storage. The faster growth of the more vigorous M.IX/XVI shoots would produce a high proportion of mature tissues more rapidly, and this would account for the earlier attainment of the final level of starch in these shoots.

Similar interpretations may be applied to the changes in hemicellulose content, though differences due to rootstock influence were more uniform. Presumably hemicelluloses were used up during the maturation of the shoot, by conversion to permanent structural materials. Such conversions would have an apparently greater effect in the case of the larger, faster-growing M.IX/XVI shoots, and hence the maintenance of the higher level of hemicellulose observed in the M.IX/IX shoots was to be anticipated.

Discussion

The results presented in this paper broadly resemble those of Mochizuki and Hanada (1957) in illustrating the depletion of carbohydrate resources at bud-break and during extension growth, and their replenishment when leaves are present without great meristematic activity. These authors described the changes occurring in sugar and starch contents in the 1 to 3-year-old portions of young apple trees of one variety, and the present work may be considered as an extension of their observations.

The present results also extend the work of Rao and Berry (1940), who used Crawley Beauty as the scion variety on M.IX and M.XIII rootstocks ; they were mainly concerned with the current season's growth of two-year-old trees between July and October, and their interpretations are overshadowed by the effect of differing rates of shoot growth and maturation on the two rootstocks. In the present work, however, an attempt has been made to differentiate in more detail between the current season's growth and the more mature regions of the tree.

The chemical analyses were based on a modified routine of extraction and isolation of carbohydrate components using a new method of sugar estimation, and it is encouraging to note that results are comparable with those of other workers. The periodate method has been found to give accurate estimation of 10-400 $\pm$ 2 μg sucrose per ml in standard solutions, and duplicate estimations of plant extracts confirm its accuracy ; it also simplified the extraction procedure because the same method of estimation could be applied to each carbohydrate fraction isolated.

The statistical analyses of the data indicated that variability between estimations for individual samples of material bulked from four trees might be of the order of 10-20% (when estimated from the error-mean-square component of the overall variance). This variability is due to the combined errors in chemical estimation, extraction, and sampling, as well as tree variation. It has already been stated that errors in chemical estimation were small and it is believed that losses in material during extraction were negligible. Errors must therefore be attributed, either to the small size of the samples from each tree, or to large differences between the trees making up the bulked samples. Even smaller samples had been used in a previous experiment without any increase in variability, so sample size seems to have had little influence on variability. Little variation in carbohydrate content along the length of a single year's growth on an older branch had previously been found, but subsequent analyses have shown a gradient along the length of a 1-year-old shoot during the dormant season, corresponding to the degree of maturity of the shoot. However, since all samples were taken from approximately the same position (midway along the units sampled) on each occasion, little error would be caused by differences in position of the sample.

The gradient which was found to exist over the root system is greater than any in the shoot system, and it was not possible to define the age group of the roots as easily as the shoots ; however, the variability of the results for the below-ground regions of the trees was not noticeably greater than for the above-ground regions. A large fraction of the error must therefore be due to tree to tree variation within each sample. This is supported by more recent work in which the selection of tree material was more rigid and in no case did the standard error of individual samples exceed 10% of the mean value.

An analysis of variance of the results illustrated in Fig. 2 (left) showed that inclusion of the effect of tree size decreased the accuracy of individual observations. It is important to note, however, that changes in the bark are of greater significance than those in the wood when results are expressed as

percentage weight of bark or wood, but that the converse applies when total weight changes are considered. This implies that estimations of carbohydrate resources are best related to the total weights of the tree and its parts, but before this can be done successfully, a method must be found for estimating or eliminating tree to tree variation.

Accurate carbohydrate analyses are unavoidably laborious owing to the need for careful isolation of each fraction, and there is a tendency to use bulk samples for estimation. The present work has shown, however, that the changes which occur in the total resources of the apple tree during the year are not confined to any particular parts of the tree. It may therefore be more useful to bulk samples from different regions of one tree and to sample more trees separately, than to bulk samples from several specific regions of a number of different trees, as was done in this instance.

Seasonal fluctuations in carbohydrate resources seem to involve each of the four fractions under discussion. The function of phloridzin is still obscure, but it is evident that the sugar, starch and hemicellulose fractions support phases of active growth and differentiation.

The similarity of the scion shoot systems of the same variety, M.IX, on M.IX or M.XVI with respect to total carbohydrate resources at the beginning and end of the season is striking. The scions on the two rootstocks differed significantly during the growing period in sugar content but not in starch content per unit of residue dry weight but further experiments are needed to assess the importance of this finding. Sugars and starch seem to form a ' pool ' of carbohydrate which is capable of supplying both energy and structural materials, whereas the evidence from the young shoots seems to imply that hemicelluloses are utilized by conversion to more complex structural compounds.

The data presented here show that extractable carbohydrates are of equal value to the scion whether they are present in a M.IX or a M.XVI rootstock, the rootstock affecting the total quantity rather than the carbohydrate composition of the scion growth. This raises the problem of what is meant by ' amount ' and ' concentration ' of carbohydrate within the plant. The various tissues of the tree are composed of different types of cell, which may be meristematic, mature, senescent or non-living, and since reserve metabolites are present only in living cells to extents which differ according to age, the amount of carbohydrate in g 100 g residue will have different significance according to the variety and the region of the tree sampled. The term ' concentration ' has been deliberately avoided since it implies ' amount in solution ', and it is as yet uncertain whether ' concentrations ' of carbohydrate would be similar between cells containing different amounts of vacuolar sap, and whether it is possible to consider polysaccharides in equilibrium with soluble sugars under the term ' concencentration '. The maintenance of a similar distribution of carbohydrate resources within the trees throughout the year would imply that there is an equilibrium between the different regions so that the ' *effective* concentration ' in one region is related to that in any other. There seems to be a relationship between the amounts of carbohydrate per unit residue dry weight of the different tissues and the relative proportions of living to dead cells within them. It is therefore suggested that some means should be sought for expressing results in terms of living cell material so that figures for tissues in equilibrium with each other, but with different proportions of living cells (e.g. bark and wood), are comparable.

It must be emphasized that this series of results indicates that carbohydrate resources were at no time at a level low enough to limit growth, but rather that the rate of growth determined the proportion by which utilization of carbohydrate exceeded its production.

Physiological studies of this type have the ultimate aim of discovering how to regulate the balance between growth and cropping of the tree most efficiently. These preliminary results make some further contribution towards the understanding of the role of carbohydrates in the support of vegetative growth ; future studies have been planned to investigate the carbohydrate requirements of fruit production.

Summary

Seasonal samples of bark and wood were taken from seven regions of six- to seven-year-old M.IX trees growing on the rootstocks M.IX and M.XVI. A new method of sugar analysis was used to obtain estimations of phloridzin, soluble sugars, starch, and hemicelluloses. Values were expressed on the basis of residue dry weight after extraction and in terms of a tree of constant size. Results indicated that sugars, starch and hemicelluloses function in support of the various phases of vegetative growth, and that the level of these resources in the tree is determined by the balance between supply from the leaves and existing cells and the demands of meristematic activity. Seasonal changes in phloridzin were not simply related to the pattern of growth. Changes in the percentage totals of extractable carbohydrates affected the whole tree, and a constant distribution between bark and wood above and below ground was maintained throughout the year. The rootstocks influenced the total quantity rather than the composition of the scion growth.

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FRUIT NUTRITION

THE SOIL MOISTURE TENSIOMETER: ITS PRACTICAL VALUE FOR FIELD USE IN FRUIT CROPS AND ITS CONSTRUCTION

By J. E. GOODE and K. J. HYRYCZ

The difficulty of measuring both the distribution of moisture in the soil and its availability has led to excessive use of empirical methods in the estimation of moisture deficit or to methods involving evaporimeters. Such estimates and measurements are liable to be affected by modifying factors, and may not accurately reflect soil moisture conditions. Their chief use, therefore, is as aids to irrigation, since they provide no information on the availability of soil moisture or on the distribution in depth of residual soil moisture. Thus the need remains to measure soil moisture *directly* in the root zone of a crop, and to express this measurement in relation to plant growth.

Soil moisture availability

Several workers (9, 12, 22) have contributed to the view that there are two factors directly concerned with the availability of soil moisture to plants, namely the ease of absorption of water in contact with roots, and the rate of water movement to them. The first of these is directly linked with the combined effects of soil moisture tension and the osmotic pressure of the soil solution. The influences of increasing osmotic pressure in a drying soil and of soil reaction to water absorption by roots are not well understood (17, 8) ; however, in non-saline soils, at tensions below that causing wilting, the influence is probably negligible (12), so that any measure of soil moisture tension at the soil-root interface would serve as an estimate of the ease of absorption of water. The second factor, related to the water transmitting properties of unsaturated soil, affects water availability according to the rate of water absorption by roots. This depends on the intensity of root ramification and on the extent of absorbing root surface in relation to the transpiring surface, as well as on the intensity of transpiration. Richards (13) has given figures for water transmission rates at unit hydraulic gradient in a fine sandy loam as follows: 2 cm/hr in saturated soil and 0·2, 0·02 and 0·002 cm/hr when soil moisture tensions were approximately 5·5, 9·0 and 15 cm Hg respectively. It is apparent that as availability in terms of soil moisture tension decreases (i.e. as soil moisture tension increases) so does availability in terms of supply to the absorbing root surfaces.

Roots in a drying soil will therefore give rise to moisture tension gradients, but these cannot be measured with present techniques. However, in soil zones well permeated with roots, equilibrium tensions may be established overnight between plant and soil (12, 17), and the measurement of these probably provides the nearest representation of soil-root interface conditions that can be obtained in the field at present.

Measurement of soil moisture tension in the field

The direct measurement of soil moisture tension is possible in the field only over a restricted range with soil moisture tensiometers. Indirect measurements can, however, be made by other means, and comparisons of different soil moisture measuring instruments made by various workers (3, 5, 7, 18, 20) have shown that the tensiometer is the most accurate and reliable instrument for measuring soil moisture tension, especially at the wetter end of the range.

The range of measurement of the tensiometer

The restricted range of the tensiometer is its chief drawback for field use, as measurement is inaccurate above about 0·8 atmosphere tension. Since absorption of soil moisture by roots may continue up to tensions of 10 or even 20 atmospheres, a measurement range of only 0·8 atmosphere appears to be quite inadequate. Richards (11) discussed this limitation of tensiometers and showed that their range covers about half of the range between field capacity and permanent wilting percentage in the finest textured soils, and 90% or more in the coarser sandy soils. Richards and Huberty (14) have confirmed this and suggest, as a result, that tensiometers are more likely to be useful indicators in the coarser soils.

This is undoubtedly correct, but in soils of limited depth, or with shallow rooted crops on deep soils, the daily rate of moisture release demanded by transpiration may give rise to such rates of moisture tension increase that measurement of tension above 1 atmosphere becomes inaccurate, and even after an overnight period measurements may not represent root-soil interface conditions because of the great reduction in rate of water movement. Hence in many soils the significant moisture measurements will be those made within the 1 atmosphere range.

Tension and soil-root relations

Moisture characteristics relating moisture content and moisture tension in drying soil do not convey readily, to those studying crop behaviour, the dynamic nature of plant-soil-water relationships. When, however, the rate of soil moisture tension increase (tension against time) is considered in relation to the moisture characteristic (tension against moisture content) and a definite volume of water

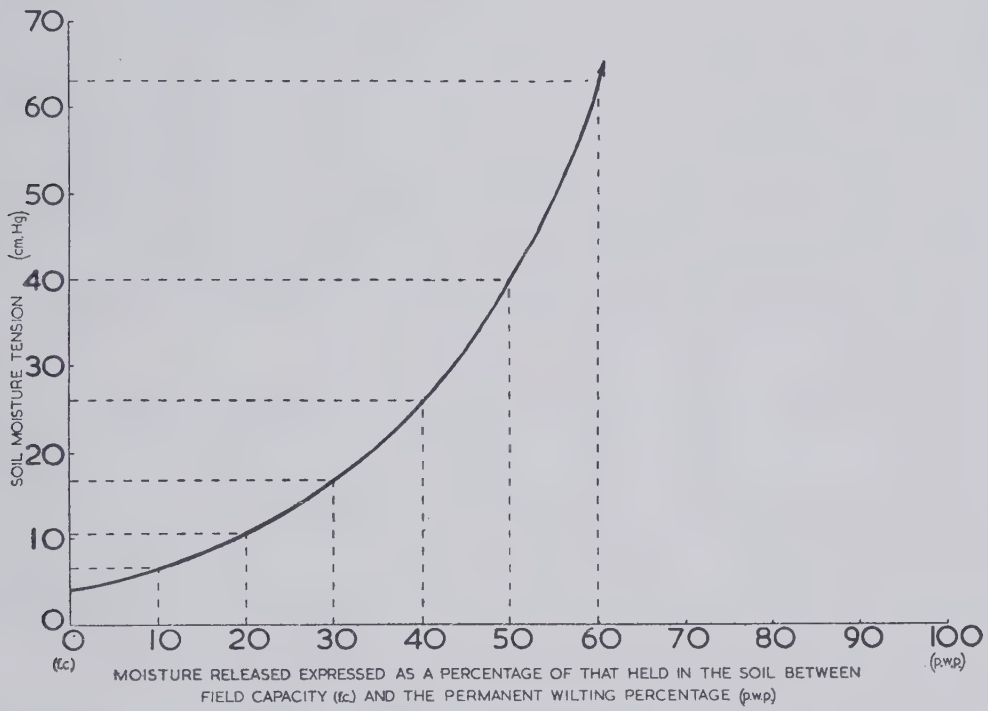

Fig. 1

Soil moisture release curve for a fine sandy loam

assigned to the root zone, it becomes easier to appreciate the conditions existing in a soil with active roots present and, under ideal conditions, to ascertain the change in root suction necessary to absorb a given amount of water in a given time.

This concept appears to discount new root extension into unexplored soil, but the root growth of an established perennial crop seems to be primarily one of repeated exploration of a given soil volume rather than of root extension as of an annual crop into new soil zones.

Fig. 1 shows the relationship between percentage available moisture released and tension for a fine sandy loam, in which 60% of available water has been removed, over the range of the tensiometer. Now supposing a complete ground cover of vegetation has a transpiration requirement of 0·1 in. of water per day which does not diminish as the soil dries, and supposing the root zone is thoroughly permeated by roots and holds 2 in. of available water, then, to maintain the transpiration rate, 5% of the total available water will need to be absorbed by the roots daily. Fig. 1 shows that whilst this quantity of water may be released by a change in tension of 1-2 cm Hg when the soil is moist, when 50% of the available moisture has been used a change of 10 cm Hg tension is required, and beyond the range of the tensiometer a change of an atmosphere or more a day may be required to release the transpiration requirement. Thus soil depth for increased root exploitation and soil structure for extensive root ramification have a wider function than the mere

provision of larger reserves of available moisture. The greater absorbing surface in deeper soils with intense root ramification means that a given rate of absorption can be maintained with much smaller rates of change in tension, and therefore in root suction, than is possible either in shallow soils or in soils with sparse root distribution. If, in the example quoted above, the soil depth made 5 in. water available for root absorption, then to maintain a transpiration rate of 0·1 in. per day only 2% of the available moisture would be required daily. Ideally, such daily subscriptions would occur with changes in soil moisture tension of only 0·5-1 cm Hg when the soil was moist, and only 4 cm Hg when 50% of the available reserves had been used.

Under normal conditions, however, uptake rates may greatly exceed the rate of water replenishment to the root surface, and steep tension gradients may be developed in the region of the root-soil interface ; measured tension changes will therefore only provide an indication of a much greater change at the root surface. Thus, while Fig. 1 may be regarded as representing measured or average tension changes in the whole volume of soil occupied by roots on the release of given amounts of moisture, the changes in tension occurring at the root surface may greatly exceed the average values. The greater the average tension changes, the steeper will be the tension gradients at the root-soil interface.

It is argued by Slatyer (21) that root uptake of moisture from drying soil can be maintained only by increasing root suction pressure (decreasing diffusion pressure). If the necessary physiological changes in the root cells cannot proceed rapidly enough to prevent loss of turgor, growth rate will be reduced initially, and this will be followed by growth stoppage and ultimately wilting (12).

If this argument is valid it seems justifiable to expect less reduction in growth resulting from high soil moisture tension when daily increases in root suction pressure are small than when they are large, i.e. when drying at the root surface is slow, as postulated by Rogers (16). The favourable condition of slow drying at root surfaces may arise from low transpiration requirements during humid and dull weather, or by large root surfaces tapping large reserves of moisture.

Location of soil moisture measurements in the crop root zone

Under all crops and in most soils the location of the root zone and the degree of permeation of the soil by absorbing roots are rather indefinite, but perennial fruit crops typically have a zone of maximum root activity which is characterized by high moisture depletion rates. Excluding the top 6 in. of soil, which is subject to wide and rapid fluctuations of moisture content, the zone of maximum root activity under fruit crops may frequently occur between 6 and 18 in. depth, provided this part of the profile is suitable for root development (1, 2). Moisture measurements made within this zone reflect conditions of moisture to which the crop will be more susceptible than to those occurring in zones of lesser root activity (6, 14). Moisture measurements made in zones of sparse root growth can provide a good indication of root-soil interface conditions only when moisture gradients are negligible—as, for example, under continuously moist conditions.

The control of soil moisture conditions using tensiometers

Tensiometers installed in the zone of maximum root activity, say at 1 ft depth for fruit crops, may be used to indicate irrigation need. It is unlikely that, for any fruit crop, irrigation would be premature if applied when the soil moisture tension reaches 50 cm Hg measured at 1 ft depth, and irrigation at much lower tensions would often be highly beneficial. The most satisfactory soil moisture condition must be that which provides readily available moisture with adequate aeration ; the tensiometer, in providing accurate information on near-saturation or saturation conditions, has a particularly useful practical value in that it indicates the depth and rate of water penetration in the soil, and hence when irrigation should cease as well as when it should begin. In addition, it takes into account automatically various other factors, such as differences in the nature and extent of vegetative cover, advective heat effects, and soil management, which may require troublesome adjustments in other methods of measuring and estimating irrigation requirement. Provided tensiometers are functioning correctly—and this is easily tested—any variation between readings taken at a similar depth from a number of locations under a crop is due to variation in soil moisture. In fact, tensiometric data derived from drying soils of the same type have been found to be relatively consistent, as is shown by the consecutive nature of all the points in Fig. 2. The soil moisture deficit was determined by calculating the difference between field capacity and gravimetrically determined water content of soil samples taken from sites near the tensiometers.

For irrigation control, an average tension derived from three or four instruments will provide an accurate guide. In the authors' experience irrigation tends to reduce variation in soil moisture under a crop, probably because more even wetting encourages even growth and more uniform permeation of the soil by roots.

Tensiometer design and development

Rogers (15) in England and Richards (9, 10) in the U.S.A. have contributed largely to the design and construction of the conventional-type tensiometer. These instruments have proved satisfactory under both field and greenhouse conditions where the soil volume has been adequate to prevent too rapid drying by crop roots. Hack (4) and Sedgley and Millington (19) have developed tensiometers with very rapid response times, which make them particularly suitable for measuring soil moisture tension where changes of tension may be very rapid, as in the soil of potted plants.

Construction of the tensiometer

Richards (10) intimated that as new materials became available they would replace those used in the construction of the tensiometer he described. This development has already occurred with the introduction of new porous material by Sedgley and Millington (19), and construction is greatly simplified and cheapened by using nylon tubing.

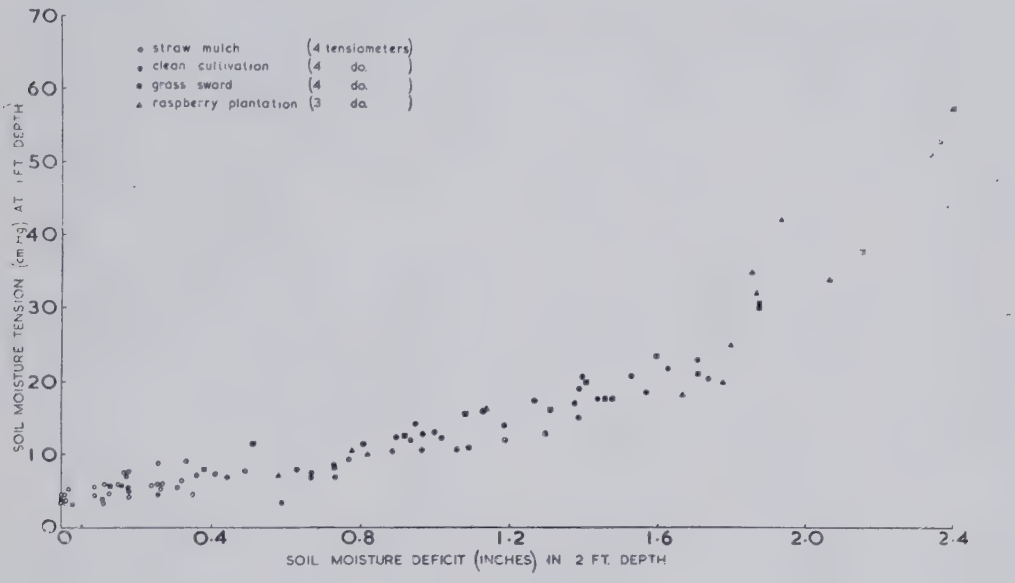

FIG. 2

Relationship between moisture tension measured at 1 ft depth and moisture deficit in 2 ft depth of a fine sandy loam soil

Conventional tensiometers, consisting of ceramic pots and nylon filling and manometer tubes, have proved completely reliable in the field for two seasons.

Fig. 3 shows the component parts of the tensiometer and the stages in its construction. On the left are the nylon filling tube, 0·50 in. external diameter and 0·375 in. internal diameter and 2-3 in. longer than the intended installation depth, and the nylon collar, 1·25 in. × 0·75 in. external diameter and 0·50 in. internal diameter. The external diameter of the collar is selected to suit the aperture in the ceramic pot. The collar is cemented on to one end of the filling tube with nylon cement and then moulded to form a flanged end to fit closely into the aperture of the ceramic pot. Moulding is achieved by rotating the base of the cemented tubes ($\frac{1}{2}$-1 in.) in a clean bunsen flame and working the plastic nylon back over the outside surface of the collar with an $\frac{1}{8}$-in. diameter metal rod until there is a uniform spread of plastic nylon. Some charring and bubbling of the nylon will occur during the heating, but with care this can be restricted. The plastic end is then pressed into a ceramic pot, the open end of which has been warmed in the flame, so that a flange of nylon forms across the top of the pot. The nylon tube and pot are held in position until the plastic nylon has hardened. An alternative method of manufacture is to cement successively larger diameter nylon collars to the base of the filling tube to give a fairly tight fit in the ceramic pot aperture.

Both thick- and thin-walled ceramic pots are commercially available and are supplied in polythene containers (not shown in Fig. 3) in which they should be kept whenever handling is necessary. The container is removed when testing and installing the instrument. Thick-walled pots are preferred

for field use since they are less liable to permit the entry of air at high soil moisture tensions, but thin-walled pots respond more rapidly to moisture tension changes in the soil and should be used where rapid tension changes are anticipated. Air leaks in pots can be detected by applying an air pressure of 1 atmosphere to the inside of a moist pot immersed in water ; if bubbling is observed the pot should be discarded.

The next stage in the construction is to remove the newly-moulded filling tube from the pot and to coat the flanged collar with Chatterton's compound. The tube is then forced hard into the ceramic pot and the whole inverted to prevent excess Chatterton's compound from running down the pot walls. When the compound has set, a further application is made externally to cover the nylon flange and to ensure a complete seal between nylon and ceramic. A smooth rounded finish is achieved by using a hot wire to work the compound. Finally, nylon manometer tubing 9 ft × 0·06 in. internal diameter and 0·10 in. external diameter* with both its ends cut obliquely is threaded first through a thin nylon washer cut from the wall of a piece of scrap tubing, and then through a hole bored in the filling tube 2 in. above the top of the pot. The tubing is pushed through until the obliquely-cut end reaches the bottom of the pot. It is then withdrawn slightly and the part to form contact with the filling tube, as well as the washer itself, is roughened slightly with sand paper, nylon cement is applied, and the tubing fully inserted and the washer pressed hard to the wall of the filling tube. Fine binding wire put round the filling tube holds the connecting surfaces together until the cement has set.

The cement takes a few days to set, but once it has hardened fusion between manometer and filling tube is complete. A rubber bung with a diameter of $\frac{7}{16}$ in. at the small end is used as a stopper for the open end of the filling tube. A polythene specimen tube 30 mm × 12·5 mm, at the right of Fig. 3, to hold 30 g clean mercury serves as an unbreakable mercury reservoir for the manometer.

Mounting

Fig. 4 shows the completed instrument mounted on a 4·5 ft × 1 in. × 1·25 in. red cedar support. A paper scale (0-76 cm), varnished on both sides to render it resistant to weathering, is secured by drawing-pins to permit easy adjustment when setting zero. The manometer tubing is inserted in a groove under the scale to the top of the wooden support and brought down the support adjacent to the scale. Staples secure the tubing without compressing it. The free, obliquely-cut end of the manometer tubing is inserted to the bottom of the mercury reservoir, which is held in a slot in the support. The bottom of the slot is cut 3 ft from the top of the support. Finally, a plastic cover is attached to the support by three hinges.

Testing

When assembled the instrument should be tested immediately. Boiled water (preferably distilled) is poured into the filling tube, and either by means of a small syringe or a glass rod used like a piston, water is forced over through the manometer tube to fill the system completely. The filling tube is topped up with water and tapping frees any air lodged in the pot. When it is certain that the whole system is air-free the bung is inserted tightly. After a few minutes the mercury should begin to rise in the manometer as a result of evaporation from the walls of the pot ; eventually a tension of 60 cm Hg or more will be reached and this should be maintained until the pot dries out. Refilling should then be repeated and if the test is satisfactory the pot should be put into its polythene cover until installed in the soil.

Installation

A hole about 3 in. in diameter is made to the required depth with a post-hole auger, the soil being removed carefully so that it can be returned in the same order. A small hand-scoop is used to prepare a cavity for the pot to ensure the best possible contact between it and the undisturbed soil. The mid-point of the pot length should be at the intended installation depth. The pot is removed from the polythene cover and inserted into the cavity, the filling tube lying against the wall of the hole bored in the soil. The soil is gradually replaced using gentle tamping to accommodate it all. The manometer tubing should be of sufficient length to permit the manometer support to be set in the soil about 2 ft from the pot installation, the connecting manometer tubing being buried in the soil. The wooden support, if driven into the soil to a depth of 12-15 in., will be quite secure. When the instrument is set in position, the bung is removed and water added until the whole system is completely air-free.

* Hack (4) has demonstrated the importance of the bore of the manometer tube in determining the response time of the instrument to tension changes. The bore used is a compromise recommended by Richards (10), but possibly a bore of 0·03 in., which is obtainable, is preferable.

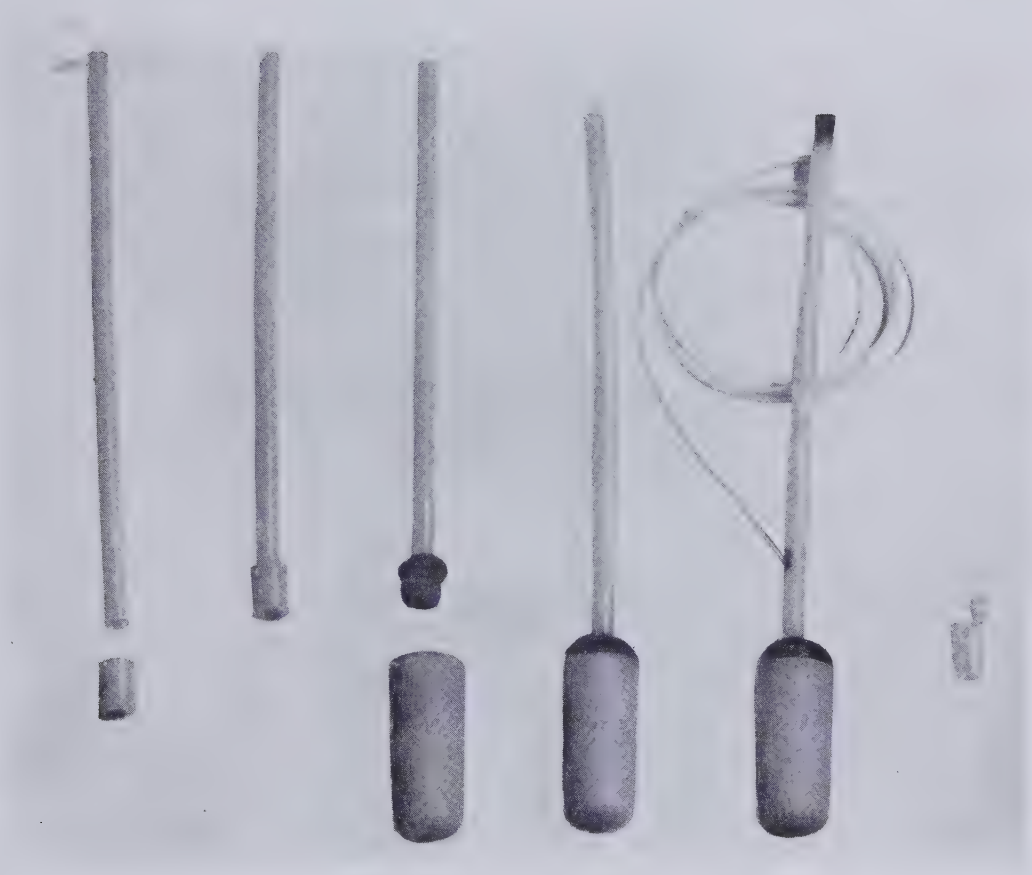

Fig. 3
Component parts and stages in fabrication of the tensiometer

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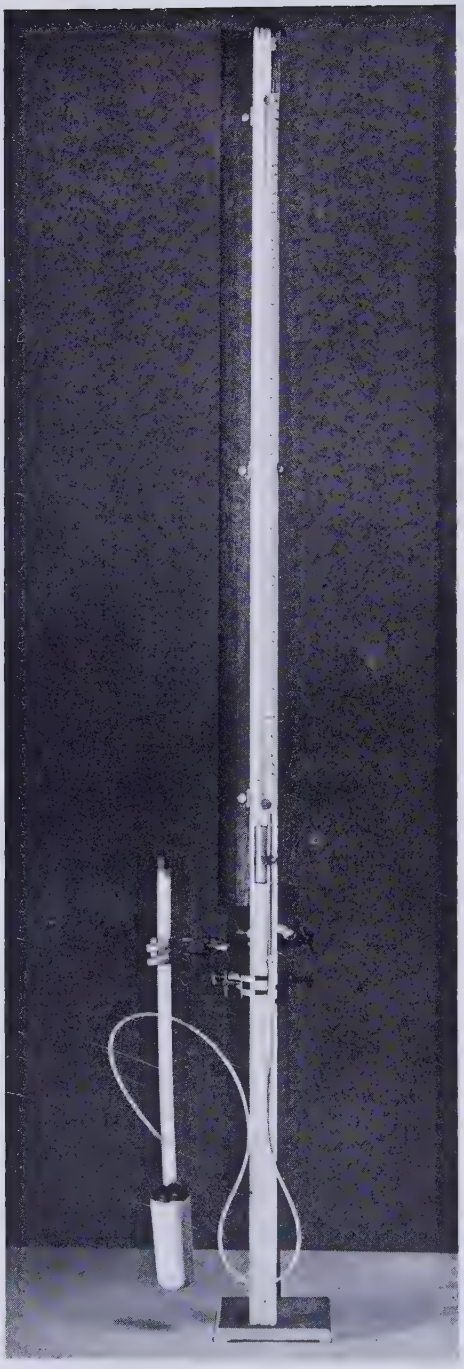

FIG. 4
The tensiometer ready for installation

Zero setting and scale readings

With the bung removed the zero of the scale is set to $\frac{h}{12 \cdot 6}$ cm above the mercury meniscus in the capillary tube, where h cm is the height of the filling tube from the centre of the pot. When zero has been set, the bung is inserted and the instrument left several days to establish equilibrium with the soil moisture tension.

Because the manometer contains water and mercury each cm rise of mercury is in fact equivalent to $\frac{12 \cdot 6}{13 \cdot 6}$ cm Hg tension = 0·926 cm. A special scale can be used, but it is found more convenient to use a centimetre scale and, when required, the correction factor.

Maintenance

During the course of the season, and especially at high tensions, air will enter the tensiometer, but it is readily detected in the above-ground portion of the filling tube. When air is present, the bung should be removed and the filling tube topped up with boiled water. On replacing the bung, equilibrium between tensiometer and soil moisture tension will be re-established within 24 hours.

Water should be withdrawn from the instrument during the winter to prevent damage from freezing.

Summary

Soil moisture availability and its measurement are discussed. The advantages of making moisture measurements in the root zone of a crop are given, and the usefulness of the tensiometer in this respect is assessed. The construction of a simple, conventional tensiometer is described.

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PLANT PATHOLOGY

EXPERIMENTS ON THE CONTROL OF APPLE CANKER BY SPRAYING

By M. H. MOORE and MARGERY BENNETT

The canker problem

In the high rainfall conditions of the fruit-growing areas in the West of England, apple canker, caused by the fungus *Nectria galligena* Bres., has long been regarded as a limiting factor in the production of healthy trees, particularly of certain dessert varieties. The literature records the results of a series of experiments at the Long Ashton Research Station extending over many years from the early studies of Wiltshire (12, 13, 14), and including contributions by various workers (1, 2, 3, 5, 10).

These writers, together with Zeller (16) in Oregon, U.S.A., agree that, although pruning and other mechanical wounds are susceptible to attack, a high proportion of new infections in the plantation is initiated at leaf-scars, and that there are two main periods of infection : (i) in autumn when the leaves fall, (ii) in spring when bud growth may cause cracking in the protective corky layer of the scars. Infection is usually more common in autumn than in spring. Old cankers in the trees provide a prolific source of spore inoculum, and new cankers often arise at leaf-scars around and below them, especially in wet conditions. Grubb (4) made similar observations in the South East, where the disease is less widespread than in the West, but does occur in epidemic proportions in certain localities following wet conditions. Moore (6) recorded infection of long-healed pruning scars and of the Y-shaped angles formed by diverging branches, and also demonstrated rootstock effects on the incidence of canker in the scion variety.

Hitherto, experiments designed in established apple plantations to control the disease by protective spraying have not promoted much confidence that a reliable protective spray programme might eventually be established (1). The incidence of infection is erratic both from tree to tree and from season to season, and the results of experiments tend to reflect the inconsistency. One experiment, started in 1940 in a heavily-infected young Cox plantation at East Malling, was continued for six consecutive seasons to test the effect of copper sprays applied just before leaf-fall and at bud-burst, both separately and in combination. The autumn and spring applications together, but not separately, reduced infection from 19 to 6 cankers on 10 trees in the second season and from 34 to 8 cankers on 10 trees in the sixth, but showed no effect in the remaining seasons, when infection was lighter. Thus spraying was most effective in the season of heaviest infection, and over the six seasons the two sprays every year reduced the total number of cankers by half (from 74 to 38 on 10 trees).

By contrast, rigorous destruction of sources of infection by cutting out and gouging old cankers has given good results, but it is a laborious process, especially on holdings where the disease has already become epidemic, as may happen very quickly under favourable conditions. Byrde, Crowdy, and Roach (1) cited one instance in Gloucestershire in which canker-excision was more effective than spraying, and in the following example a deliberate attempt was made at East Malling to restore a young plantation of four interplanted apple varieties, each on M.IX at 12 ft square, that had become almost derelict through canker alone. By careful cutting out and gouging, 706 cankers were removed from 210 trees of Cox's Orange Pippin, 732 from 231 of Beauty of Bath, 165 from 77 of Worcester Pearmain, and 72 from 77 trees of Duchess Favourite. These figures represent means per tree of 3·3, 3·2, 2·1, and 0·9 for the four varieties respectively. Thus 1,675 cankers were destroyed on 595 trees. The wounds were not painted, and, as in an earlier trial (6), did not become re-infected. Subsequently, isolated infections were easily removed as they occurred, and the plantation eventually became profitable. The trees undoubtedly remained susceptible to canker, though not liable to further severe outbreaks because sources of infection were regularly suppressed.

From what was then known of the merits of spray treatment, it is most unlikely that such effective control would have been achieved by spraying alone. Nevertheless, a satisfactory protective spray programme would probably prevent epidemics, and, moreover, could hold an existing epidemic in check by greatly reducing satellite infection while the old cankers were being removed. Byrde, Crowdy, and Roach (1) have shown that an eradicant spray of 0·3% phenyl mercury chloride, by suppressing sporulation of the old cankers for a time, can achieve a similar result by different means, but this spray is costly and its use might therefore have to be restricted to the nursery and young plantations.

The 1940 spray experiment already referred to had indicated that more consistent success might depend on critical timing, especially of autumn sprays. Post-war research at East Malling has therefore been concentrated on intensive methods for investigating problems that have proved difficult to study satisfactorily on a plantation scale, and hedges of the very susceptible rootstock M.VIII (7) were used as host material.

Exploratory experiments, 1947-53

I. To find the period(s) of greatest natural infection from autumn to spring

Material and methods

M.VIII rootstocks were planted singly at 15 in. apart in the row, and established as bushy plants by annual cutting back. Inoculum was provided by natural cankers collected from infected trees ; they were kept in damp grass for a few days to develop the sporing stages (either as conidial pustules or as perithecia), and then tied in to the stocks as shown in Fig. 1. The row was divided into six equal sections, and cankers were tied in to each section in turn each month from November to March, and removed after one month's exposure. The remaining section, a control, received no cankers throughout the period. After the first two seasons, few cankers had been found on either the January or the February sections, so these two were replaced by October and April, thus extending the test period. All new cankers were removed when recorded in the following summer.

Results

The results, expressed as total numbers of new cankers per 10 plants, are shown in Table I. A large proportion of these cankers had clearly originated at the leaf-scars, though some were recorded at branch bifurcations (see Fig. 4) and burr-knots (6, 7).

Table I

Periods of natural infection by the canker fungus

1947/48		1948/49		1949/50	
Exposure to prepared inoculum	No. new cankers, 1948	Exposure to prepared inoculum	No. new cankers, 1949	Exposure to prepared inoculum	No. new cankers, 1950
				3 Oct.-3 Nov.	9
11 Nov.*-11 Dec.	6	2 Nov.†-2 Dec.	32	3 Nov.‡-3 Dec.	23
11 Dec.-12 Jan.	2	2 Dec.-3 Jan.	20	3 Dec.-4 Jan.	36
14 Jan.-14 Feb.	0	3 Jan.-2 Feb.	2		
14 Feb.-12 Mar.	0	2 Feb.-2 Mar.	1		
12 Mar.-13 Apr.	0	2 Mar.-4 Apr.	3	6 Mar.-3 Apr.	9
				3 Apr.-4 May	0
Not exposed (control)	0	Not exposed (control)	1	Not exposed (control)	4

* Defoliation almost complete. † Main defoliation period starting.
‡ Main defoliation period started during 2nd week November.

Infection was very localized, and the pattern suggests that on these low-growing stocks even ascospores were dispersed over only a short range, and that water was probably the chief spore-dispersing agent (3, 10, 16), as shown by the paucity of cankers on plants not provided with inoculum. Throughout the 3-year period tied-in cankers were examined every time they were removed after the month's exposure, and there was never any difficulty in finding mature perithecia and ascospores.

There was a main peak of infection in November and December during and soon after leaf-fall ; a much smaller peak in March, covering the bud-burst period ; and none from 3 April onwards. Evidently slight infection was possible also between the peaks, and this could be appreciable if multiplied on a plantation scale. It should be specially noted that in 1949 infection occurred before *general* leaf-fall began, and probably, as in 1948, for a considerable period afterwards ; Wiltshire and Spinks (15) had, in 1920, observed bud infections before defoliation was complete. The variation in the time of the autumn infection period from one season to another probably stems from the effects of differing weather conditions on the dispersal of inoculum and the time and extent of the leaf-fall period.

These results, obtained under quasi-natural conditions, are in general agreement with the observations of Zeller (16) in Oregon, but differ in some respects from those of Marsh (5) at Long Ashton,

Fig. 1

Method of tying-in sporing cankers as inoculum for M.VIII rootstocks (photo., April, 1942).

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FIG. 2

Left: Severe bud damage in spring 1953 from sodium endoxohexahydrophthalate applied at 0·5% in October 1952
Right: Normal bud break in unsprayed control section

FIG. 3

Part of unsprayed section of row of M.VIII rootstocks at time of recording, showing dead shoots through infection resulting from cankers tied-in the previous autumn

FIG. 4

Close view of sporing cankers on M.VIII rootstocks near ground level, showing typical sites of infection other than at leaf scars

obtained under artificial conditions. Marsh applied mycelium in agar to leaf-scars of young Cox trees in pots, and lesions developed from inoculations made in October or April, few from those in March (these trees were checked by transplanting), and none from those in November or January. The main differences relate to the respective November and April series, and may be a consequence of differing experimental conditions.

On the basis of the information obtained from this series of experiments, the next included spray treatments.

II. To investigate the timing of autumn sprays

Material and methods

The same small planting of M.VIII rootstocks was used for the spray experiments, and freshly-prepared 1% Bordeaux mixture (10–15–100), i.e. 0·25% Cu., was selected as a standard treatment, including enough spreader to provide uniform coverage without excessive run-off. For these small bushes a hand-operated pump was adequate.

As the leaf-fall periods may be protracted, some experiments included tests of a hormone defoliant, sodium endoxohexahydrophthalate at 0·5%, but, after showing much promise the first season, this hormone later caused such severe bud injury (Fig. 2) that these experiments were discontinued.

Cankers were collected and tied, as before, to all plants before spraying began ; they were removed at the end of December.

Results

Three years' results are shown in Table II, again expressed as total numbers of new cankers per 10 plants.

TABLE II

THE EFFECT OF AUTUMN SPRAYS OF 1% BORDEAUX MIXTURE ON CANKER INFECTION

1950/51			1951/52			1952/53		
Dates of spraying, 1950	% Defoliation†	No. new cankers, 1951	Dates of spraying, 1951	% Defoliation†	No. new cankers, 1952	Dates of spraying, 1952	% Defoliation†	No. new cankers, 1953
27 Sept. and 11 Oct.	5 / <30	38	25 Oct.	40–60	50	1 Oct. and 15 Oct.	<20 / 50–60	26
			25 Oct. and 28 Nov.	40–60 / 90–100	66			
11 Oct.	<30	43				15 Oct.	80–100	51
11 Oct. and 7 Nov.	<30 / 80–90	15	25 Oct.* and 28 Nov.*	40–60 / 90–100	50			
Nil		37	Nil		64	Nil		56
						Nil		57

† Means of estimations per plant. * Sprayed with a cuprous oxide preparation at 0·2% Cu.

No appreciable control was shown by a single spray-application in any of the three seasons—a result in agreement with previous experience in plantation experiments. Two sprays, one soon after leaf-fall began and the other when it was well advanced in 1950 and in the 'earlier' season of 1952, reduced infection by rather more than half, but two sprays during the early stages of leaf-fall in 1950 had no effect. In 1951, the sprays were apparently applied too late to have much effect ; indeed, the Bordeaux spray at the end of leaf-fall may well have vitiated any slight effect of the earlier spray by impairing the fresh protective scar tissue. It is possible also that any effect of the autumn sprays was masked that year by satellite infection in March 1952, which was unusually wet (and see 1958-59 results, p. 89).

These results provided a working basis for larger-scale intensive experiments on statistical lines ; fresh rows of M.VIII stocks were therefore established and became suitable for use in 1956.

EXPERIMENTS, 1956-59

The timing of autumn sprays for canker control

Material and methods

M.VIII rootstocks were planted at 1 × 8 ft in three 320 ft rows. Experiments were conducted in series, to allow for the cutting back and resuscitation of each row in turn after use. Sporing

cankers were collected, prepared, and tied in to each plant before spraying began, as in the earlier experiments ; these cankers were removed at the end of January.

Sprays were applied hydraulically by lance from a mobile 50-gal. machine at *c.* 200 lb/sq. in. pressure, and a small screen arrested spray drift. Each plot comprised 10 plants, and there were eight replications of four randomized treatments.

Treatments (1956 and 1957) :

(*a*) Before leaf-fall became general*
1. Ferrous sulphate crystals, 2·5% by wt.
2. Ferrous sulphate as 1(*a*).
3. Bordeaux powder as 1(*b*).
4. Nil (control).

(*b*) During general leaf-fall
Bordeaux wettable powder (15% Cu), 1·67% by wt.
Water† (control).
Bordeaux powder as 1(*b*).
Water† (control).

* Slight leaf-fall might already have occurred.
† Included to simulate any effect of the sprays in washing spores from the cankers.

Ferrous sulphate had already shown success as a defoliant in pilot experiments, and was included to shorten the leaf-fall period so that more leaf-scars could be directly protected by the second spray. This device had already been employed, with Bordeaux mixture as the defoliant, on cherries for the control of bacterial canker (9), but Bordeaux had not shown similar consistency in defoliating apple rootstocks. A proprietary Bordeaux powder of known copper content was used in these experiments because many growers prefer not to prepare the fresh mixture.

Results

Two years' results are summarized in Table III as the mean total number of new cankers, per plot of 10 plants, recorded and cut out each summer following infection. Part of a severely cankered, unsprayed control section is illustrated in Fig. 3.

The most effective treatment, No. 3, consisting of two Bordeaux powder sprays in sequence, each of 0·25% Cu content, reduced infection by nearly 90% in both seasons, thus clearly substantiating the results of the earlier experiments. Ferrous sulphate was more effective as a defoliant in 1957 than in 1956, but the Bordeaux powder (No. 3) was but little inferior in this respect, for many leaves were removed by the second (17 Oct.) spray in 1957, as the leaf-fall records of 14 and 18 Oct. show. A single spray of ferrous sulphate alone (No. 2) reduced canker infection, which in 1957 but not in 1956 was further decreased by a later spray of the Bordeaux powder ; ferrous sulphate, however, blackened and destroyed many of the perithecia on the tied-in cankers, and this probably contributed to its effectiveness.

TABLE III

THE CONTROL OF APPLE CANKER BY AUTUMN SPRAYS I

Treatment	1956/57 Dates of spraying, 1956: (*a*) 24 Oct.† (*b*) 15 Nov.			1957/58 Dates of spraying, 1957: (*a*) 3 Oct.† (*b*) 17 Oct.		
	% Defoliation‡ before spraying at (*b*)	Mean total no. new cankers, 1957	Mean total shoot length (metres)	% Defoliation‡ (i) 14 Oct. (ii) 18 Oct.	Mean total no. new cankers, 1958	Mean total shoot length (metres)
1 (*a*) Ferrous sulphate ..	80–90	1·9*	74·9	(i) 70–80	6·5***	147·5
(*b*) Bordeaux powder ..				(ii) 100		
2 (*a*) Ferrous sulphate ..	80–90	1·9*	72·1	(i) 70–80	10·4**	139·8
(*b*) Water				(ii) 100		
3 (*a*) Bordeaux powder ..	90–100	0·5**	72·9	(i) 5–10	2·5***	143·0
(*b*) Bordeaux powder ..				(ii) 70–80		
4 (*a*) Nil	50–60	4·0	74·0	(i) 5–10	20·4	144·3
(*b*) Water				(ii) 40–50		
Significant difference, P = 0·05		1·86			5·97	

Significant difference from controls: *P <0·05 **P <0·01 ***P <0·001
† Leaf-fall very slight. ‡ Means of estimations per plant.

Growth of the rootstocks was uniform throughout the plots, and there was thus no indication that the browning of leaves and premature defoliation caused by the ferrous and the copper sprays had had any deleterious effect on the stocks, which also presented comparable targets for the spores in each of the treatments.

Treatments (1958)

By the summer of 1958 it was clear that, although ferrous sulphate had contributed substantially to canker control in the previous two seasons, its effect as a combined defoliant, eradicant, and possibly protectant was inferior to that of the Bordeaux powder acting primarily as a protectant with defoliant and possibly slight eradicant properties as well. It was therefore decided to modify the treatments in autumn 1958, and re-randomize them on the same row ; to assess the timing of sprays as before ; but to omit ferrous sulphate in favour of a comparison of the Bordeaux powder with its copper equivalent (0·25%) as freshly-made Bordeaux mixture.

The modified treatments were :

A. Bordeaux wettable powder, 1·67% by wt., applied at (*a*) and (*b*) (see p. 88).
B. The same, but applied only at (*b*).
C. As A, but with freshly-made Bordeaux mixture (10–15–100) and spreader instead of powder.
D. Nil (control) except for water at (*b*) as before.

Results

The results were recorded in summer 1959, and are summarized in Table IV as the mean total number of new cankers per plot of 10 plants.

TABLE IV

THE CONTROL OF APPLE CANKER BY AUTUMN SPRAYS II

1958/59

Dates of spraying, 1958: (*a*) 7 Oct. (1% leaf-fall)
(*b*) 26 Oct.

Treatment	% Defoliation (i) 25 Oct. (ii) 27 Oct.	Mean total no. new cankers, 1959
A (*a*) Bordeaux powder	(i) 30–40	67·5
(*b*) Bordeaux powder	(ii) 80–90	
B (*a*) Nil	(i) 20–25	73·0
(*b*) Bordeaux powder	(ii) 50–60	
C (*a*) Bordeaux mixture	(i) 20–25	63·5
(*b*) Bordeaux mixture	(ii) 50–60	
D (*a*) Nil	(i) 15–20	66·6
(*b*) Water	(ii) 50–60	
		n.s.

The results show no significant differences at a high level of canker infection, and thus are apparently at variance with those of the previous two seasons (Table III). It was not until the data were reclassified in relation to the *1957* spray treatments that the reason became clear :

Spray treatment, 1957 (see p. 88)	1	2	3	4
No. new cankers, 1959	44·1**	71·0**	53·5**	107·6

Significant difference (P = 0·05), 29·08 ** Significant at P <0.01

The results now broadly reflect the 1957-58 data (Table III), though the significant superiority of treatments No. 1 and 3 has been lost in a general increase in infection. Thus the cankers represented by the data in Table III, although excised when recorded at the end of July 1958, had had a greater influence on the pattern of infection recorded a year later than either the cankers tied in or the sprays applied in autumn 1958. Evidently the only feasible explanation is that in the exceptionally high rainfall of June 1958 (3·98 in. : 35-yr av., 1·63 in. (11)), the cankers then approaching the recording stage had already initiated undetected secondary infections, which developed to form the bulk of the cankers recorded in 1959.

It is pertinent to recall here that both Grubb (4) and Moore (6) demonstrated some control of

canker by foliage sprays applied in May and June. Control of leaf-scar infection in this way would probably be due chiefly to the retention of leaves that would otherwise drop early from scab and mildew. Defoliation by spray damage also may increase liability to canker (6). Premature leaf-fall through scab and mildew, to which M.VIII stocks are very subject, would probably account for some of the satellite canker infections in the present instance, but infection was not confined to the leaf-scars as Fig. 4 shows.

Although the intended fungicidal comparison of the two forms of Bordeaux mixture was thus nullified, and will be repeated in another experiment, it should be noted that the powder, but not the freshly-made mixture, accelerated defoliation.

Conclusions and recommendations

The results of these intensive experiments on unworked M.VIII rootstocks, together with the indications from earlier experiments in fruiting plantations, permit the following conclusions to be drawn, and enable some basic recommendations to be made. Meantime, investigations of fungicide programmes are being continued, and these include an examination of materials other than copper preparations.

1. Copper sprays can considerably reduce the incidence of new cankers even when the environment is experimentally weighted in favour of heavy infection by the provision of numerous sporing cankers as inoculum.

2. Autumn sprays alone are unlikely to give complete control, especially when followed by wet weather in the following spring and summer ; the annual frequency will depend to some extent on the locality. At least one further copper spray would be advisable, to be applied when the buds are beginning to swell. Marsh (5) suggested the addition of Bordeaux mixture to the petroleum-oil spray then used against certain insect pests as a component of the routine spray programme, and a copper/petroleum spray was in fact included with some success in the 1940 spray experiment at East Malling referred to on p. 85. Although other sprays have since replaced petroleum oil and also its successor, DNC-petroleum, there is still much to be said for the use of a copper spray with DNC-petroleum at bud-swelling for the combined reduction of insect pests with apple canker and apple mildew if the situation warrants this choice (8).

3. Any success obtained from a single autumn (or winter) spray will probably depend largely on a chance coincidence of its application with a single, short period when a combination of conditions particularly favours infection. It may be for this reason that Wiltshire (14) was unable to show any control by a Bordeaux spray in November, though Wiltshire and Spinks (15) had greatly reduced infection by spraying individual branches in the field with copper stearate in mid-December. Two sprays are much to be preferred ; the first before general leaf-fall begins, and the second at about the half-way stage, as after leaf-fall may be too late (*pace* Marsh (5)), especially under wet conditions. The first spray, particularly if Bordeaux powder is preferred to freshly-made Bordeaux, may condition the leaves for ready removal by the spray-jets at the second application, and this would probably be an advantage. The approximate dates for the spraying and the interval between applications cannot be predicted with certainty as they will greatly depend on seasonal conditions.

It cannot be too strongly urged that the spray programme outlined above must be seen as only one stage in an effort to conquer an *existing* canker problem. It is essential to couple with it the systematic removal of the old sporing cankers, as is recommended also by Byrde, Crowdy, and Roach (1). This operation should be completed where possible between the autumn and spring sprays. Where both spraying and cutting out are thoroughly done in good time, a severely-infected plantation can be restored to good condition in one season, though naturally where the branch framework has been mutilated to some extent, restoration to full cropping must await the production of suitable new cropping ' wood '. Thereafter the still susceptible but canker-free trees can be kept from a further epidemic by the protective spray programme, coupled with the removal of any new infections as they occur. These are, however, unlikely to be numerous in the absence of sporing cankers and where the spray programme is maintained as routine for as long as necessary.

Where canker is a serious problem it is especially desirable to ensure safe and efficient control of apple scab (13) and apple mildew, for early defoliation by these diseases, and by spray damage, would expose leaf-scars to canker infection at a period when the specific canker sprays recommended above would be ineffective.

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Summary

A series of experiments extending over several seasons on the susceptible M.VIII apple rootstock showed that the incidence of apple canker (*Nectria galligena* Bres.) could be greatly reduced by two copper sprays applied in autumn, the first before the main leaf-fall period started and the second at about 50% leaf-fall. At least one further application is advisable in spring when the buds begin to swell, especially for localities of high spring rainfall.

Where a severe epidemic already exists, this spray programme must be supplemented by thorough excision of the old cankers, preferably between the autumn and spring sprays.

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VIRUS DISEASES OF CHERRY TREES IN ENGLAND
III. CROP REDUCTION CAUSED BY SOME VIRUSES

By A. F. POSNETTE and R. CROPLEY

The effect of certain viruses on the growth of the mazzard rootstock, F12/1, was described by the writers in 1956 (6) and the reduction in crop caused by sour cherry yellows virus in Montmorency cherries has been assessed by various workers (1, 3, 4). No reports have appeared of the losses caused by virus diseases in sweet cherries, however, and the field trials described here were started in 1953 to provide information on the relative economic importance of those viruses that are commonly found latent in nursery trees.

Materials and method

In one trial, 28-year-old trees of Early Rivers and Turkey Heart were used. The plot had originally been planted as a rootstock trial, and the crops of the individual trees had been recorded each year since they began fruiting. Each tree was tested for virus infection by inoculation on F12/1 indicator plants and all the Turkey Heart trees were found to contain a virus causing rust coloured areas and necrotic spots on F12/1. As this virus did not produce symptoms in Shirofugen cherry or peach it was regarded as distinct from necrotic ring spot and called rusty mottle (5), although the symptoms on cherry are now known to be different from those caused by American forms of rusty mottle. The Early Rivers trees proved to be infected with ring mottle virus which also failed to affect peach, sour cherry and Shirofugen cherry.

Before the results of this indexing were known, the orchard trees were inoculated by grafting four branches on each tree with scions infected with one of the following:

1. European rusty mottle virus.
2. European rugose mosaic virus.
3. Tatter leaf caused by ' non-recurrent ' necrotic ring spot virus and sour cherry yellows.
4. Necrotic line pattern caused by ' recurrent ' necrotic ring spot virus and sour cherry yellows.

Eight trees of each variety were inoculated with each virus source and eight left uninoculated as controls.

In a second trial, trees of Early Rivers, Napoleon, Merton Bigarreau, and Merton Heart were propagated on F12/1 stocks using scionwood from a single tree of each variety that had been tested and found free from known viruses. When the trees were one year old they were each inoculated by patch grafting with one of the same four virus sources used in Experiment 1, or with the ring mottle virus found in the orchard trees of Early Rivers. They were then planted out in November 1953 with uninoculated controls in a randomized layout (12 replications) at 12 × 15 ft spacing.

Results

Trial 1—Mature trees

The tatter leaf and necrotic line pattern diseases caused severe leaf scorch on the inoculated branches in the first year after infection, and on other parts of the tree in the second and third years. Subsequently the trees with tatter leaf developed no necrotic spots on their foliage ; those with necrotic line pattern showed no recovery, however, and their leaves were severely scorched each year. Leaf symptoms were more severe on Early Rivers than on Turkey Heart, but trees of the latter variety appeared to suffer the more severe check in growth with necrotic line pattern.

Neither rugose mosaic nor rusty mottle viruses produced more than transient symptoms on the trees, and they had little effect on yield, in marked contrast to the two necrotic ring spot/sour cherry yellows viruses.

In the fourth, fifth, and sixth years after inoculation, non-recurrent tatter leaf reduced the crop of Early Rivers by 52% and of Turkey Heart by 37%, while recurrent necrotic line pattern reduced the crops in these two varieties by 72 and 73% respectively (Figs. 1 and 2 ; Table I).

Trial 2—Young trees

The girth of the trees was measured annually at 2 ft above ground level. Infected trees grew less vigorously than the controls (Table II), as had previously been observed when mazzard F12/1

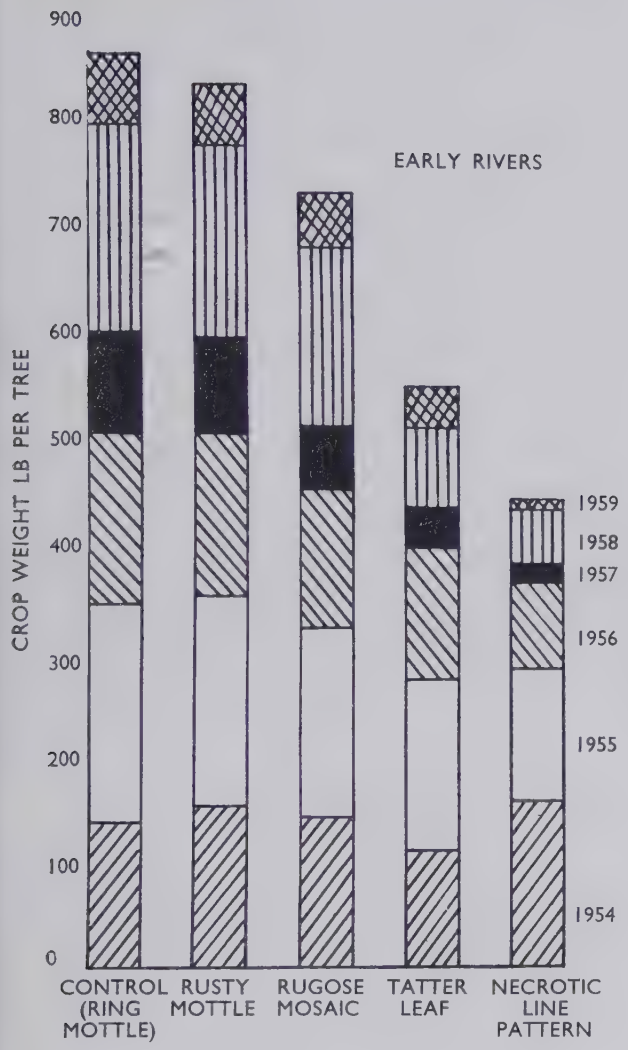

FIG. 1
Mature trees. Crop weights of Early Rivers

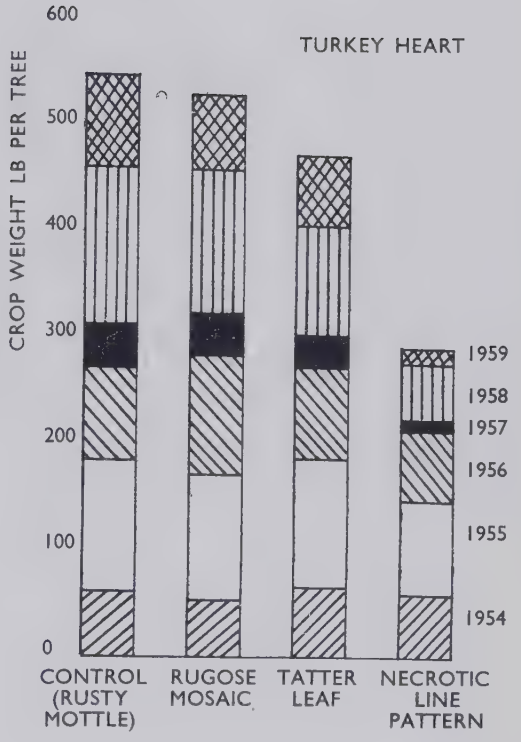

FIG. 2
Mature trees. Crop weights of Turkey Heart

TABLE I

MATURE TREES. WEIGHT OF FRUIT (LB) PER TREE, 1957-59

	Control	Rusty mottle	Rugose mosaic	Tatter leaf	Necrotic line pattern	Significant difference (P = 0·05)
Early Rivers	341·0	333·1	273·7	165·6	95·7	82·4
Turkey Heart	294·6	—	242·1	186·9	79·6	67·4

plants were inoculated with other isolates of these viruses (6). Trees with ring mottle were the least affected and those with tatter leaf and necrotic line pattern the most stunted. The yield from these trees has been erratic, as is usual with the first crops of young cherry trees. In the varieties Early Rivers, Merton Bigarreau and Napoleon, rusty mottle and rugose mosaic caused about 20% reduction in crop ; this is proportional to the reduction in tree size when calculated from girth measurements.

TABLE II

YOUNG TREES. MEAN TRUNK GIRTHS, 1958, EXPRESSED AS PERCENTAGES OF CONTROLS

	Control		Ring mottle	Rusty mottle	Rugose mosaic	Tatter leaf	Necrotic line pattern	*Significant difference (P = 0·05)
	Girth (cm)	%	%	%	%	%	%	%
Early Rivers ..	25·8	100	94·4	87·9	93·0	80·4	79·3	6·2
Merton Bigarreau	36·6	100	95·3	88·5	86·3	73·5	75·4	6·3
Napoleon	32·4	100	89·2	83·0	81·5	69·4	68·5	9·8
Merton Heart ..	29·5	100	101·7	95·2	97·6	83·7	74·2	6·0

* The significant difference applies to differences between the controls and any one of the virus treatments, but not to differences between any two of the virus treatments.

Tatter leaf and necrotic line pattern reduced the crop by approximately 70% (Table III), compared with a reduction of about 50% in tree size.

TABLE III

YOUNG TREES. WEIGHT OF FRUIT UP TO 1959, EXPRESSED AS PERCENTAGE OF CONTROLS

	Control		Ring mottle	Rusty mottle	Rugose mosaic	Tatter leaf	Necrotic line pattern	Significant difference (P = 0·05)
	lb per tree	%	%	%	%	%	%	%
Early Rivers ..	26·4	100	62·5	72·3	77·7	31·8	27·7	11·7
Merton Bigarreau	39·7	100	105·5	82·6	68·0	28·5	33·5	15·4
Napoleon	13·4	100	108·9	75·4	56·7	23·1	28·4	26·1

Trees of Merton Heart behaved differently from the other varieties : when infected with rusty mottle, rugose mosaic and tatter leaf they cropped twice as heavily as the control trees (Table IV).

TABLE IV

YOUNG TREES. WEIGHT OF FRUIT (LB) PER TREE OF MERTON HEART

	Control	Ring mottle	Rusty mottle	Rugose mosaic	Tatter leaf	Necrotic line pattern	Significant difference (P = 0·05)
1957	2·1	2·1	4·1	4·6	4·2	0·9	0·6
1958	5·9	5·8	7·0	14·6	14·1	2·4	1·8
1959	1·8	2·0	5·1	5·3	2·9	1·1	0·8
Total	9·8	9·9	16·2	24·5	21·2	4·4	

All the Merton Heart trees have developed a splitting and roughening of the bark similar to the condition described as virus canker of the Frogmore variety (7). Attempts to demonstrate transmission of this rough bark condition from Merton Heart to other varieties have failed so far, and no Merton Heart trees entirely free from rough bark have been found. In the cropping trial, the control trees and those infected with ring mottle showed most bark splitting, while trees with tatter leaf and necrotic line pattern showed least. The abnormal bark on the vigorous trees might, therefore, be the cause of their low cropping, and further research is needed on this interesting example of virus infection increasing the crop of one variety while depressing that of others.

Discussion

The results of these trials indicate that virus infection in cherry trees is of greater economic importance than was formerly realized. All the viruses used in these trials, with the exception of the

very mild ring mottle virus, reduced the cropping of four of the five varieties tested. The most spectacular effect is that of tatter leaf on the cropping of mature Early Rivers trees, the crop being reduced by 52% even during the years when trees had recovered from the ' shock ' phase of the disease and showed no leaf symptoms.

Orchard surveys, and tests on more than 400 sweet cherry trees in Kent have shown that over 90% are infected with one or more of the viruses used in these trials. Because of the varying incidence of bacterial canker, it is impossible to assess accurately the economic importance of cherry viruses, but there is little doubt that in most commercial orchards an annual reduction in potential crop of at least 20% is incurred as a result of virus infection.

Virus-tested F12/1 rootstocks and eighteen commercial cherry varieties have been issued from East Malling under the ' Mother Tree ' scheme (2, 8). Some nurserymen have availed themselves of this material, and are now offering trees for sale. The modes of natural spread of these cherry viruses are not known, and some orchards planted with healthy trees may become infected. There is no doubt, however, that healthy trees will be more productive, especially when young, than those propagated from orchard trees most of which are now known to be virus-infected.

Summary

Cherry trees inoculated with viruses prevalent in Britain yielded less than uninoculated trees. The crops of mature Early Rivers trees were reduced by 72% by necrotic line pattern and 52% by tatter leaf ; the crops of mature trees of Turkey Heart were reduced by 73 and 37% by these two viruses respectively. Yields of young Early Rivers, Napoleon, and Merton Bigarreau trees were reduced by rusty mottle, rugose mosaic, tatter leaf, and necrotic line pattern. Young trees of the variety Merton Heart behaved differently, most of the infected trees cropping more heavily than uninoculated trees. This may be due to a rough-bark condition, of unknown cause, that developed on all the Merton Heart trees, and was more severe on the vigorous trees than on those stunted by virus infection.

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STRAWBERRY MOSAIC AND APPLE MOSAIC VIRUS IN STRAWBERRY

By R. CROPLEY, CHRISTINA E. ELLENBERGER and ASHARFI JHA

Posnette (4) described as ' strawberry mosaic ' a virus disease causing yellow areas and distortion in leaves of Royal Sovereign strawberry. Similar symptoms were later induced on plants of this variety when apple mosaic virus was transmitted from apple and plum by grafting (1). The experiments described below have shown that despite this resemblance in symptoms, strawberry mosaic is caused not by the apple mosaic/plum line pattern virus, but by a strain of the soil-borne virus named raspberry yellow dwarf by Harrison (2) and now known (Cadman, in the press) to be Arabis mosaic virus (5).

Transmission of apple mosaic virus to strawberry

During 1956, D. J. Engelbrecht (at East Malling on study leave from Stellenbosch, South Africa) transferred apple mosaic virus from apple and plum by grafting to strawberry plants. *Fragaria vesca* plants developed a chlorotic leaf pattern (Fig. 1) and in Royal Sovereign the symptoms were of the mosaic type (Fig. 2), although less severe than those of typical strawberry mosaic disease. The latter was known to involve multiple infection with three viruses, as the aphid-transmitted mottle and crinkle viruses were both present in the ' type ' plants (4). These aphid-borne viruses were therefore transmitted by grafting to the strawberry plants infected with apple mosaic virus, but although the symptoms became more severe, particularly when both mottle and crinkle viruses were added, the chlorotic pattern and leaf distortion was different from that on plants with strawberry mosaic (Fig. 3).

Sap transmission experiments

Royal Sovereign strawberry leaves from plants with mosaic collected from Somerset and Kent, and from plants graft-infected with apple mosaic virus, were macerated in five times their own weight of M/15 phosphate buffer pH 7·8. ' Celite ' abrasive was added, and the inoculum was then rubbed on to the cotyledons of young cucumber plants. The cucumber plants inoculated with sap from both the Kent and Somerset types of strawberry mosaic developed very mild chlorotic spotting on the cotyledons, followed by severe yellow mottling on the second and third true leaves. Symptoms in *Chenopodium amaranticolor*, plant protection tests in *Petunia hybrida*, and serological tests with raspberry yellow dwarf antiserum (kindly supplied by Dr. B. D. Harrison) showed that the virus transmitted was a strain of raspberry yellow dwarf. Repeated attempts have failed to demonstrate sap transmission to cucumber, *Petunia*, and *Chenopodium* of virus from Royal Sovereign and *Fragaria vesca* plants infected with apple mosaic.

Discussion

Symptoms of raspberry yellow dwarf virus in strawberry are extremely variable because varieties differ in tolerance, and strains of the virus differ in pathogenicity. Lister (3) transmitted this virus from Cambridge Favourite strawberry plants that were severely stunted, with yellow blotches on their distorted leaves. We have transmitted the virus from stunted plants of the strawberry variety Huxley's Giant that had chlorotic spotting and vein chlorosis on the leaves ; similar symptoms were induced on healthy Huxley plants when grafted to Royal Sovereign plants having strawberry mosaic. Some strains of raspberry yellow dwarf virus cause leaf distortion, necrotic spotting and occasional diffuse yellow spots on Royal Sovereign, while others, such as those transmitted from plants with strawberry mosaic, produce well-defined bright yellow areas on the leaves. Symptoms on strawberry are therefore a poor guide to diagnosis, and sap transmission to herbaceous plants is the only sure means of distinguishing the soil-borne virus diseases from those caused by other viruses.

Summary

Strawberry mosaic of the variety Royal Sovereign is caused by certain strains of the soil-borne raspberry yellow dwarf (Arabis mosaic) virus. Apple mosaic, an apparently unrelated virus, caused similar symptoms when transmitted to strawberry by grafting.

Fig. 1
Symptoms of apple mosaic virus on *Fragaria vesca*

Fig. 2
Symptoms of apple mosaic virus on Royal Sovereign

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FIG. 3

Strawberry mosaic on Royal Sovereign, caused by raspberry yellow dwarf virus (arabis mosaic)

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THE USE OF CUTTINGS AND HEAT TREATMENT TO OBTAIN VIRUS-FREE STRAWBERRY PLANTS

By A. F. POSNETTE and ASHARFI JHA

One of the buds excised from the stem of a heat-treated strawberry plant proved to be without crinkle virus, although the parent plant remained infected (1). This suggested that heat therapy might be more effective if several plants could be raised from the axillary buds on each treated plant. Smith and Harland (2) described a method of propagating strawberries, particularly useful for non-runnering varieties, by sectioning the ' crown ' of the plant. This method has now been applied to virus-infected plants after heat treatment.

Material and methods

Crinkle and vein chlorosis viruses (viruses 3 and 4 Prentice) had proved difficult to inactivate by maintaining plants for several weeks at 37° C. (1). Plants infected with these viruses were therefore used, the varieties being Huxley's Giant with vein chlorosis and Cambridge Favourite with both vein chlorosis and crinkle viruses.

Trials with unheated Huxley's Giant plants were made on the size of cutting, comparing discs of 1 and 0·5 cm thickness cut by slicing the stem (' crown ') transversely, and also on the rooting medium. The size of the cuttings had no influence on the proportion that rooted, and about one third of each set became established (1 cm cuttings, 21/60 and 0·5 cm cuttings, 19/60). When a mixture of equal volumes of peat and coarse sand was compared as the rooting medium with either peat or sand alone, the numbers rooted out of 47 cuttings were peat 17, sand 19, and mixture 20.

Heat treatment decreased the proportion of cuttings that became established. In one trial with Cambridge Favourite, for example, using peat-sand mixture as the rooting medium, 15 cuttings survived out of 47 from unheated plants, compared with 5 out of 52 from plants kept for 2 weeks at 37° C.

The plants raised from cuttings were virus-tested by stolon-grafting to *Fragaria vesca* indicator plants. Most of the plants were tested in two consecutive years with Frazier's UC-1 clone and a new East Malling clone, VS 1, to indicate infection with crinkle and vein chlorosis viruses respectively.

Results

Two of five cuttings taken from Cambridge Favourite plants after 2 weeks' treatment, and four of five from those treated for 3 weeks proved to be free from crinkle virus. This should be contrasted with previous results of heat treatment without taking cuttings, when no plants were cured after periods up to 40 days (1).

The vein chlorosis virus causes only mild symptoms even on the best indicator variety available (VS 1) and diagnosis is impossible if crinkle virus is also present. Symptom expression varied from plant to plant so that repeated tests over several seasons may be necessary to prove beyond all doubt that a plant is not infected. Tests on 24 cuttings from Huxley plants that were not heat-treated, however, showed all but two to be infected with vein chlorosis virus. These two plants will be retested repeatedly to find out whether the virus is latent, or if it is possible to obtain healthy plants by taking cuttings without heat treatment, should the virus not be fully systemic in the plant.

Of six plants (Huxley's Giant and Favourite) grown from cuttings taken from plants after 3 weeks' treatment at 37° C, four have induced no symptoms on the indicator plants after virus tests in two consecutive years.

These results indicate that even those viruses which have so far proved resistant to heat treatment may be eliminated from future propagation stocks of commercial varieties of strawberries.

Summary

After treatment at 37° C for 2 or 3 weeks, strawberry plants of Cambridge Favourite and Huxley's Giant were propagated from 0·5-1 cm disc cuttings. Some of the plants so raised were found to be free from crinkle virus (virus 3 Prentice) and probably also from vein chlorosis virus. These viruses had persisted in entire plants kept at 37° C for up to 40 days.

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HEAT INACTIVATION OF SOME VIRUSES IN PLUM VARIETIES AND ROOTSTOCKS

By CHRISTINA E. ELLENBERGER

Tests for virus infection were carried out on trees of Victoria, Ontario, and Ruth Gerstetter plums, and on the clonal rootstocks Marianna and Common Plum, in order to find virus-free material for propagation. Italian Prune was used as an indicator for prune dwarf, Cambridge Gage for bark split (2), and peach seedlings for necrotic ringspot and for the virus causing a dark green sunken mottle on peach leaves, a latent virus common in plums and rarely occurring in cherry (3). Seedlings of mazzard cherry were used as indicators for cherry ring mottle virus. No virus-free source of these plum varieties was found and an attempt was therefore made to remove the infection from sources of known virus content by heat treatment.

Treatment of Common Plum rootstocks

Materials and methods

Rooted layers of Common Plum, known to be infected with bark split and peach green mottle viruses, were potted in 6-in. pots in the autumn of 1955. In July 1956 eight of these, with well-established root systems, were cut back and put into the heat chamber. Previous work with heat treatment of apple (4), cherry (1), and strawberry (5), had suggested that a temperature of 37° C would probably be the highest that plums would tolerate for long periods and the plums were therefore maintained in the heat-chamber at 37±2° C. The first plant was taken out after 15 days and the others subsequently at 3- to 4-day intervals.

The young shoots that had grown out during the treatment were cut off, and buds from them grafted on to Myrobalan B seedlings or virus-free Brompton stocks. New plants were propagated by this method from each of the heat-treated plants except those maintained for 18 and 39 days.

Results

Some of the young plants of Common Plum derived from heat-treated buds were indexed (virus-tested) on peach seedlings in 1957 ; all proved to be still infected with the dark green mottle virus and were discarded without being tested for bark split virus. In 1958 the remaining plants were top-grafted with Cambridge Gage scions to test for bark split virus. Before this was done scions from each Common Plum were grafted on to virus-free Brompton stocks, to preserve material free from infection by any unknown virus that might be latent in the Cambridge Gage scionwood. All the Common Plum plants were also tested for peach green mottle virus by chip-budding on to three peach seedlings, two chips being placed on each seedling. Some of these chips did not form permanent unions with the peaches, and on 30 of the seedlings that did develop symptoms the plum chips were dead when they were examined 5 weeks after budding. Since in these cases temporary unions between the chips and the peach seedlings had sufficed for transmission of green mottle virus, the negative results in Table I are considered valid indications of the absence of this virus from the plants under test.

Treatment of plums infected with peach green mottle virus

The sources of Marianna and Ontario and one source of Victoria selected for heat treatment were infected with peach green mottle virus only.

Material of Marianna suitable for heat treatment was prepared by potting rooted layers from five clones in autumn 1956. In June 1957 nine plants were cut back and placed in the heat chamber. After 29 days at 37±2° C, only four, each from a different clone, were still growing ; the terminal growth of the other plants had been killed. The extreme tips of the new growth were propagated by grafting on to actively growing young Myrobalan B seedlings. Each scion was $\frac{3}{8}$-$\frac{1}{2}$ in. long, and consisted of the terminal bud and just enough of the stem to be cut into a wedge shape.

To obtain plants of Victoria and Ontario suitable for heat treatment, virus-free Brompton stocks were potted in autumn 1956 and grafted in January 1957 with scions of the virus-tested sources. In July, eight plants of Victoria/Brompton and one of Ontario/Brompton were prepared by cutting back the shoots, and the plants were maintained in the heat chamber at a temperature of 37±2° C. After 39 days five of the Victoria plants and the one Ontario were still growing, but the others had been

TABLE I

RESULTS OF HEAT TREATMENT OF SIX PLANTS OF COMMON PLUM AT 37(±2)° C

Infected 'parent' Common Plum	Days treated	Plants propagated	Results of testing progeny for:	
			Bark split virus	Green mottle virus
H612/1	15	1	o	+
		1	+	−
H612/3	22	3	o	+
H612/4	25	2	o	+
		4	+	−
		9	+	+
H612/5	28	2	o	+
		1	+	−
		1	+	+
H612/6	32	1	o	+
		3	−	−
		7	−	+
		1	+	−
		2	+	+
H612/7	35	3	o	+
		4	−	+
		1	−	−

Note: + = infected; − = not infected; o = not tested.

damaged by the heat and the new growth had withered. Tips were cut from the undamaged shoots and grafted on to Myrobalan B seedlings.

Results

The Victoria grafts failed, but two Ontario and nine Marianna scions survived, and in the following summer these were further propagated by budding on to virus-free stocks in the nursery. They were also indexed for green mottle virus by chip-budding on peach seedlings. None of the inoculated peach seedlings developed symptoms in 1958 or 1959, although all the plum scions had united successfully with them. Peach seedlings inoculated at the same time with buds known to be infected with green mottle virus developed the usual symptoms. The tests on peach seedlings were repeated in 1959, and again showed that the plants propagated from heat-treated plants were virus-free.

The original treated plants of Victoria and Ontario were indexed on peach seedlings 9 months after the treatment and were found free from peach green mottle virus ; this had evidently been eliminated from the entire plants. Two of the four Marianna plants that had survived the heat treatment had since died ; the two survivors were found to be still infected with green mottle virus.

Treatment of Ruth Gerstetter plum

Virus-free Brompton stocks were grown in pots and grafted with scions of Ruth Gerstetter infected with bark split and severe plum line pattern viruses. Only one plant of Ruth Gerstetter was sufficiently well grown to be treated, and this was showing line pattern when put into the heat chamber. It was treated for 39 days at 37° C at the same time as the Ontario and Victoria plants.

Five Ruth Gerstetter tips were grafted on to seedlings, but only one of these grew. This plant was indexed on peach in 1958 and again in 1959 and was found free from line-pattern virus. Tests for bark split virus are not yet complete.

By April 1958, the heat-treated ' parent ' plant had developed the same line pattern that had been evident before treatment ; it was therefore not retested.

Treatment of Victoria plum

The second source of Victoria selected for heat treatment was infected with an unidentified virus causing wilting, necrosis, and death of young shoots in peach, with chlorosis of the young leaves

and extensive chlorotic spotting and mosaic in the old leaves. Scions of this source were grafted on to potted Brompton stocks and four plants for treatment were thus obtained.

One plant survived after 39 days at 37° C and scions from it were tip-grafted on to seedlings. One of these scions grew and was found to be virus-free when indexed on peach seedlings in 1958 and 1959. The heat-treated Victoria plant, from which the new virus-free plant had been derived, was shown to be still infected.

Discussion

These experiments have shown that plum material can be freed from certain viruses by heat treatment. Clearly the host plant is concerned in the inactivation since peach green mottle virus was eliminated from some varieties of plum more readily than others ; thus entire plants of Victoria and Ontario were freed from this virus whereas treated Marianna plants remained infected, although virus-free scions could be cut from the tips of growth made at 37° C.

The use of heat therapy to separate the components of complex virus infection is exemplified by the results of the treatment of Common Plum rootstocks.

Summary

Virus-infected plants of three scion varieties of plum and two clonal rootstocks were treated for periods of 15-39 days at 37° C ; virus-free material was then propagated from growth made during the treatment. Plum bark split, plum line pattern, and peach green mottle viruses were eliminated and also an unidentified virus causing necrosis and mosaic in peach seedling indicators.

The green mottle virus was inactivated from entire plants of Victoria and Ontario, but Marianna plants remained infected, although virus-free material was propagated from the tips of shoots grown at 37° C.

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A VIRUS-DEGENERATION OF LOGANBERRY

By J. T. LEGG

During the past twenty years a decrease in yield of fruit and in cane vigour has led to a reduction in the acreage of loganberries in England. The low yields cannot be attributed to the planting of weak seedling types, as a decline in vigour and cropping has occurred in plantations of the East Malling clone (1). The possibility that the weakening or ' degeneration ' of loganberry plants may be caused by a virus—as in the ' symptomless decline ' of Lloyd George raspberry (3)—has now been investigated.

Materials and method

Two weak but otherwise normal plants of the East Malling clone, one from a commercial nursery (532/1) and the other (13/12) from a trial at East Malling, and a weak thornless sport (9/12) were tested for virus infection. Tests were also made on a vigorous plant of the East Malling clone obtained from Long Ashton Research Station and on ten other vigorous loganberry plants collected from Eire, Canada, and New Zealand (1). The virus test plants were chosen from those species that had proved useful indicators for viruses in *Rubus* plants (4). Scions from each of the vigorous loganberry plants were bottle-grafted to test plants of *Rubus henryi, R. occidentalis,* and *R. saxatilis,* and scions from five of the plants were also grafted to plants of Lloyd George and Norfolk Giant (*R. idaeus*). These four species and *R. albescens* were used for the virus tests of the three degenerate plants. No evidence was obtained of virus infection of the vigorous plants but some of the *R. henryi* plants grafted with degenerate scions developed symptoms. The aphids, *Amphorophora rubi* (Kalt.) and *Aphis idaei* v. d. G. were tested as vectors with long and short acquisition-feeding times, but no *R. henryi* test plants developed symptoms.

Symptoms on *Rubus henryi*

In 1955, scions from each of the degenerate loganberries were grafted to *R. henryi* plants. Symptoms appeared on one of the three plants grafted with 532/1, on one of those grafted with 9/12, and on all three plants grafted with 13/12.

Affected plants showed shock symptoms 6 to 12 weeks after being grafted ; growth was weak and some of the leaves developed a chlorotic ring pattern or extensive chlorosis (Fig. 1). Symptoms in subsequent years consisted of weak growth, short internodes, and a yellowing of the interveinal and leaf-edge tissues (Fig. 2). No symptoms appeared on any of the ungrafted control plants.

In further tests of these three degenerate loganberry plants only 2 out of 24 grafted *R. henryi* plants developed shock symptoms, although 11 other plants showed chronic symptoms in the following year.

Effect of the isolated virus on loganberry plants

When the presence of a virus had been demonstrated in degenerate loganberry plants, a field trial was planned to assess its effect on cropping when inoculated into vigorous plants. Four plants of the virus-tested clone 460/2 were used, two inoculated with the virus from a *R. henryi* plant infected from loganberry 13/12 (treatments A and C), and two controls left ungrafted (treatments B and D). The plants were propagated by leaf-bud cuttings in autumn 1957, and young plants were grown through the winter with additional heat and light. In the following spring, ten plants of apparently equal vigour were selected from each parent and planted in a trial of ten randomized blocks, each block containing one plant of each of the four treatments. The plants were fan trained on wirework 6 ft high.

In 1959, the first year of fruiting, the crop from each plant was weighed and immediately after harvest the old cane was cut and weighed. There were no differences between similar treatments, i.e. A and C, or B and D, but both the crop and cane weight from infected plants were significantly lower than those from healthy control plants (Table I).

Discussion

The presence of a virus in weak loganberry plants and its absence from vigorous ones suggested that this virus is responsible for the degeneration. Further evidence was obtained from the reduction

Fig. 1

Leaves of *R. henryi*, showing the chlorosis and ring-pattern shock symptoms after infection with loganberry degeneration virus

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FIG. 2

Shoots of *R. henryi*: *left*, from a healthy plant, and *right*, from a plant infected with loganberry degeneration virus, showing the chronic symptoms of short internodes and chlorosis

of vigour and crop of plants after inoculation, although the possibility remains that the loss of vigour may be caused at least in part by a virus other than that causing symptoms in *R. henryi*.

Wilhelm (7) reported that a virus disease, dwarf, was responsible for a rapid decrease in the acreage of loganberries in California, and another dwarfing disease of loganberry was described by Zeller in Oregon (8). Both these diseases and rubus stunt (6) produce unmistakable leaf and stem symptoms on loganberry and on other *Rubus* hosts, whereas the degenerate loganberries examined at East Malling showed no obvious abnormalities. In the range of test plants used, symptoms developed only on *R. henryi* and these were distinct from the necrosis caused by some of the aphid-borne raspberry viruses (2). It is considered, therefore, that the virus transmitted from loganberry has not been described previously and the name proposed is ' loganberry degeneration virus '.

TABLE I

LOGANBERRY FRUIT AND CANE YIELDS IN 1959

	Mean weight (lb per plant)	
Treatments	Infected A C	Healthy B D
Fruit	5·1	8·0*
Cane	2·7	4·1*

* $P = 0.001$.

At the beginning of this investigation no vigorous stocks of loganberry were available to growers. In 1954, a plant of the East Malling loganberry clone was obtained from Long Ashton Research Station and shown to be free from loganberry degeneration virus. Rooted cuttings from this plant were returned for propagation to Long Ashton Research Station and later offered to the Nuclear Stock Association for propagation under the conditions of a Special Stock Certification Scheme (5). Plants of this clone, known as LY59, are now available to the industry.

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The Director, D.S.I.R., Auckland, New Zealand, Dr. R. Stace-Smith, University of British Columbia, Canada, and Mr. A. Turner, Department of Agriculture, Eire, supplied the vigorous loganberry plants. Dr. C. H. Cadman provided the *Rubus henryi, R. saxatilis, R. idaeus* vars. Lloyd George and Norfolk Giant indicator plants, Dr. R. Stace-Smith the *R. albescens* seed and Dr. R. L. Knight the *R. occidentalis*.

Summary

A virus detected in weak plants, but not found in any of the vigorous plants tested, was shown to be responsible for the degeneration of loganberries. The name loganberry degeneration virus is proposed for the virus which caused symptoms in *R. henryi*, but not in any of the other *Rubus* hosts used.

A vigorous virus-tested stock (LY59) is now available to the industry.

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PEAR BLISTER CANKER: A VIRUS DISEASE

By R. CROPLEY

Unhealthy bark conditions of pear trees are encountered in most countries where pears are grown. Stony pit virus is associated with an ' oak bark ' condition in some pear varieties such as Bosc (2), and bark necrosis virus (4) produces symptoms on certain quince and pear seedlings, but the cause of many unhealthy bark conditions of pears remains obscure. A bark canker disease of Williams' Bon Chrétien has been investigated and shown to be graft-transmissible.

Material and method

In March 1957 certain 1-year-old Williams' trees on Quince A rootstocks with Beurré Hardy intermediates (1) developed blisters and bark splitting on the main stem, while others planted nearby were unaffected. Reference to the sources of budwood showed that the diseased and the healthy trees had been propagated from different Williams' and Beurré Hardy trees which were healthy in appearance and had been tested previously for known latent viruses by grafting to quince indicator plants (3). The following combinations had been used :

Williams' ' 1 ' with Hardy ' A ' intermediate produced diseased trees.
Williams' ' 2 ' with Hardy ' B ' intermediate produced healthy trees.

To investigate the cause of the bark cankers, ten Quince A rootstocks were budded in July 1957 with each of the source trees as follows :

(i) Williams' ' 1 ' with Hardy ' A ' intermediate ;
(ii) Williams' ' 2 ' with Hardy ' A ' intermediate ;
(iii) Williams' ' 1 ' with Hardy ' B ' intermediate ;
(iv) Williams' ' 2 ' with Hardy ' B ' intermediate.

In 1958 the nursery trees in sets (iii) and (iv) were slightly more vigorous than those in sets (i) and (ii), which showed epinasty of the leaves at the bases of the main stems. The trees were lifted from the nursery and planted out in January 1959. In February small blisters appeared on the stems of trees in sets (i) and (ii), followed by longitudinal splits in the bark (Fig. 1) which became severely cankered (Fig. 2). Examination of the unions revealed severe phloem necrosis in the Williams' scions, but the Beurré Hardy intermediate and Quince A rootstocks were unaffected. By July all the Williams' scions in sets (1) and (ii) had died, and the Quince A rootstocks were producing vigorous suckers. Trees in sets (iii) and (iv) showed none of these symptoms and grew into normal two-year-old trees. These results indicate that Beurré Hardy ' A ' is infected with a virus that produces no obvious symptoms in Beurré Hardy or Quince A, but causes blister cankers, phloem necrosis and sometimes death of Williams'. This virus differs from others previously reported in pear, and the name Pear Blister Canker Virus is proposed.

Summary

A virus-induced canker disease of pear trees is described. The virus was transmitted by grafting from a symptomless tree of Beurré Hardy to Williams' Bon Chrétien, causing slight epinasty of the leaves in the year after budding, and blister cankers, phloem necrosis and sometimes death the following year. The name Pear Blister Canker Virus is proposed.

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Fig. 1

Early stage in development of blister canker on Williams' Bon Chrétien

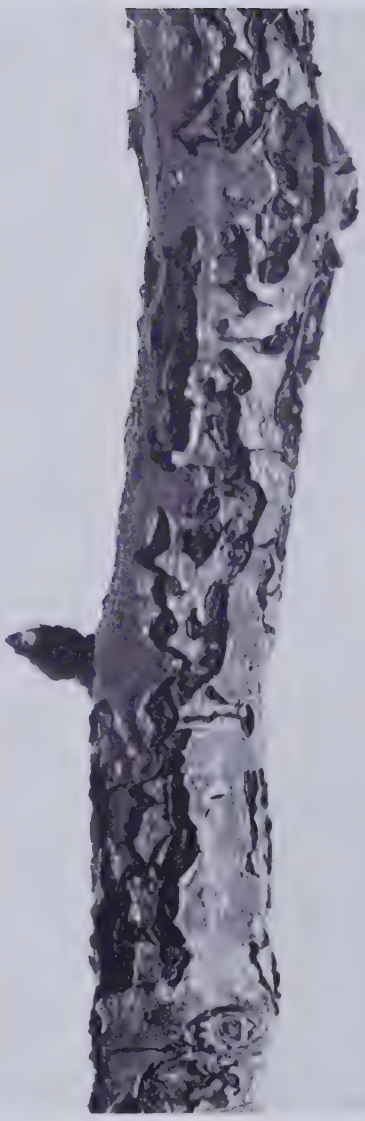

Fig. 2

Later stage in development of blister cankers on Williams' Bon Chrétien

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ENTOMOLOGY

A FIELD STUDY OF THE SPREAD OF APTEROUS FORMS OF THE STRAWBERRY APHID, *PENTATRICHOPUS FRAGAEFOLII* (COCK.)

By G. H. L. DICKER

Whilst there is little doubt that immigrant, virus-infected, winged aphids are mainly responsible for primary infections of the mottle, yellow-edge and crinkle type viruses which appear in young strawberry beds, the mode of subsequent spread is still uncertain. Alatae undoubtedly play a part, but since immature and apterous aphids, which are efficient vectors under glasshouse conditions (2), are present on strawberry plants throughout the year (1), it seems likely that these also are responsible for local virus spread within the plot. The movements of wingless forms of the strawberry aphid have therefore been studied under field conditions on first-year strawberry plants in two successive years.

Methods

Layout

The variety Royal Sovereign was used in both trials, runners being planted at $1\frac{1}{2} \times 3$ ft spacing in the preceding autumn. The plot contained four rows, each of 121 plants, in 1955 and three rows, each of 101 plants, in 1956.

Initial infestation

Winged forms of the strawberry aphid occur during two well defined periods (1), in May and June when the main flight takes place, and from October until January ; only an occasional one is produced during the intervening summer months. The period chosen for observation thus began in July when the risk of new foci of infestation arising from progeny of incoming alatae was minimal. Prior to this the plants had been exposed to infestation by alatae during the spring dispersal phase and, to remove any aphids present, they were thoroughly sprayed twice with 0·08% nicotine during the week preceding inoculation, and subsequently carefully inspected. The centre plant in each row, numbered zero in Figs. 1 and 2, was then infested with about 80 aphids, comprising both apterae and nymphs, from an insectary-reared colony. This was done on 23rd July 1955 and 4th July 1956.

Method of recording

Each plant was examined for the presence or absence of aphids. The youngest leaves were first inspected and searching continued towards the older basal leaves until aphids had been found or all the leaves had been examined. Inspections were made weekly in 1955 and at approximately monthly intervals in 1956.

The 1955 experiment

The progress of aphid spread, following inoculation on 23rd July, is shown in Fig. 1 which illustrates only that portion of the plot containing infested plants. Aphids spread along the rows, sometimes in a discontinuous pattern until, by 23rd August, the most distant infestations had reached the tenth plant to the north and the seventh to the south from the original source. Thereafter no spread took place in a northerly direction, whilst to the south there was only slight additional plant to plant spread together with occasional new isolated infestations on more distant plants.

A feature of the distribution of infested plants was the failure of aphids to maintain colonies throughout the period of observation on all the inoculated plants and also on many which had previously been observed to be infested. Between 23rd August and 27th September the number of infested plants steadily declined, in spite of a few additional ones becoming newly colonized between each inspection ; this was followed by an increase in October and November. Two factors adversely affecting the establishment of thriving colonies were an attack of verticillium wilt, which caused severe stunting on many plants, and predation by both adult and immature stages of *Anthocoris nemorum* (L.), which probably migrated from adjoining plum trees following the suppression of a heavy infestation of the fruit tree red spider mite.

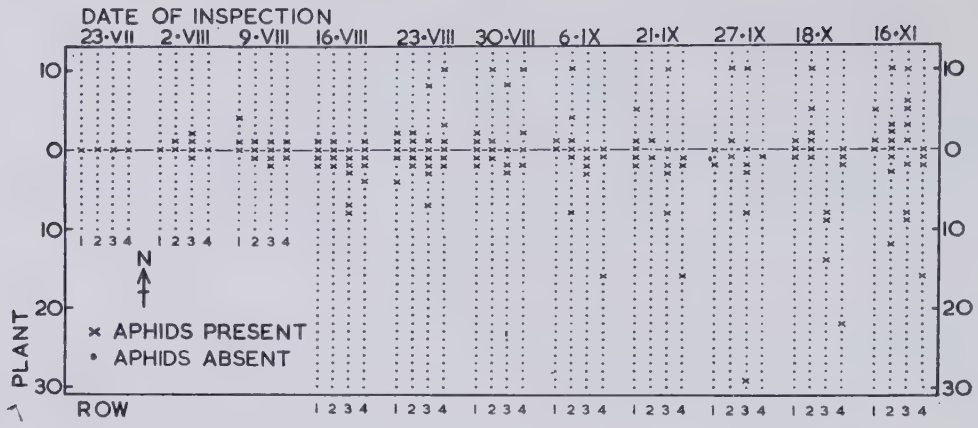

FIG. 1

The spread of aphid infestation from a focal point as recorded at each inspection in 1955

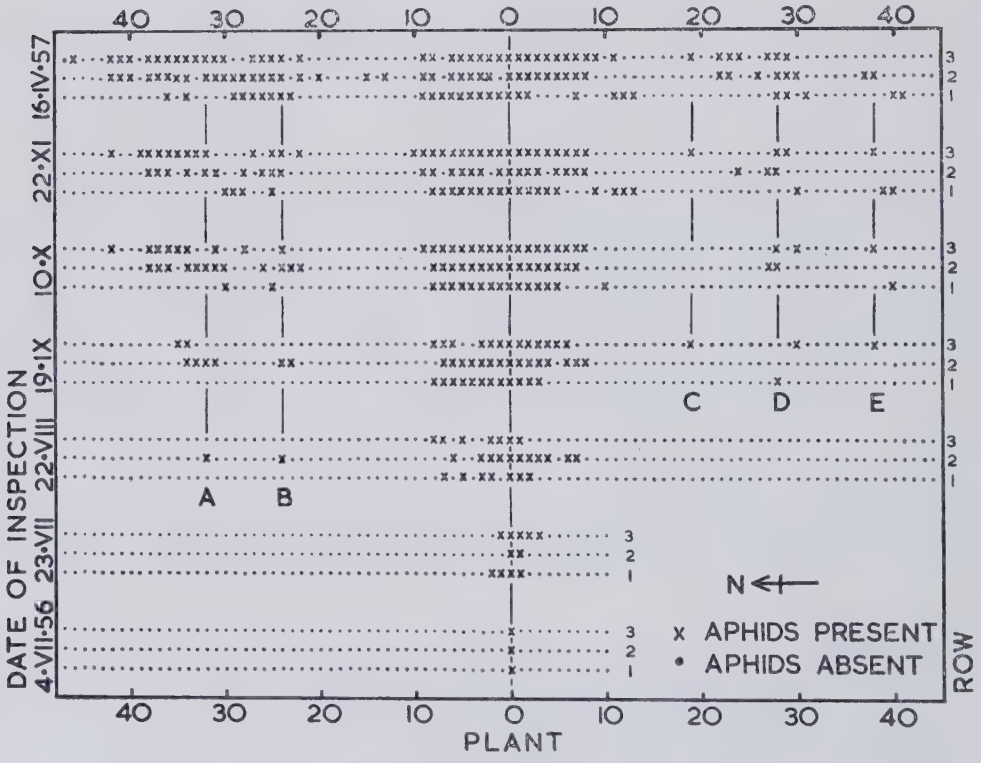

FIG. 2

The spread of aphid infestation from a focal point as recorded at each inspection in 1956-57

The 1956 experiment

In describing this experiment it will be convenient to make a distinction between local spread, in which it is considered new plants were colonized by apterous or immature aphids derived from the original stock whose movement was unaided, and the appearance of new foci of infestation, so distant from previous ones that they could only have arisen from aphids transported by some mechanical means or from nymphs deposited by alatae.

Local spread from the original source

As shown in Fig. 2 and Table I there was a relatively rapid spread along the rows from the original source of infestation up to 19th September when the most distant aphids had reached the eighth plant on either side. Movement at the extremities of the infested area continued at a reduced rate, reaching the tenth and thirteenth plants on the north and south sides respectively by 22nd November. A further inspection, on 16th April 1957, showed the distribution and number of infested plants to be very similar to that observed in the previous November.

TABLE I

THE NUMBER OF INFESTED PLANTS OBSERVED AT INTERVALS DURING THE 1956 EXPERIMENT

Date	Site of infestation						Total	% plants infested
	Original	A	B	C	D	E		
4th July, 1956	3	—	—	—	—	—	3	1
23rd July	11	—	—	—	—	—	11	3·6
22nd August	25	1	1	—	—	—	27	8·9
19th September	40	6	2	1	2	1	52	17·2
10th October	49	23		0	4	2	78	25·7
22nd November	52	27		1	6	3	89	29·4
16th April, 1957	53	46		1	15	4	119	39·3

Infestations arising from new foci

On 22nd August plants 24 and 32 in the northern half of row two were found to be infested. Aphids spread from these two points and by 10th October had merged into one diffusely infested area. The spread was more rapid from point A than from B and essentially in a northerly direction along rows two and three. Four further foci of infestation appeared in the southern half of the plot by 19th September, two of these (point D) being so close together that it was impossible to distinguish subsequent spread from individual plants. By 22nd November no spread had occurred from C, whilst that from D and E was restricted to only a few plants. Between 22nd November and 16th April 1957 a further marked increase in the number of infested plants took place only from points A-B and D.

Discussion

Although there were marked differences in the actual number of plants infested in the two experiments, a similar basic pattern of aphid spread can be discerned. Local spread along or across the rows was greatest between July and September, but continued at a reduced rate until late November ; this resulted in aphids colonizing a discrete area extending over about ten plants, or a distance of 15 ft, in each direction from the original source of infestation. Much of this movement, as shown in Figs. 1 and 2, was to adjacent plants and can be directly attributed to walking aphids. The factors which cause this movement are probably associated with leaf development since Kennedy, Ibbotson and Booth (3) have demonstrated a marked reduction in the preference of *Aphis fabae* Scop. and *Myzus persicae* (Sulz.) for fully expanded leaves, and a similar phenomenon has been observed with *P. fragaefolii*. It would seem, therefore, that much of the plant to plant spread might have been due to aphids which left maturing leaves and, failing to find a suitable young leaf nearby, wandered off the plant.

There were also occasions when newly infested plants were noted at varying distances from the nearest recorded source. In most instances the distance was not more than four plants, or 6 ft, and the aphids could either have walked or have been mechanically transported. Other new foci of infestation occurred at much greater distances and could only have arisen from nymphs deposited by alatae, or from aphids mechanically transported during cultural operations, or on wind-borne plant debris. With the exception of the northerly spread from point A during late September and early October 1956, which was relatively rapid, aphids spread out from these focal points during the autumn at a rate very similar to that observed from the original source.

By comparing the distribution of infested plants on 22nd November 1956 and 16th April 1957 it can be seen that very little spread took place during this period except from the points A-B and D. The weather during the winter of 1956-57 was exceptionally mild, with the minimum grass temperature not falling below 19° F. These conditions were very favourable for survival and reproduction

of the strawberry aphid and permitted the overwintering population to be maintained at an exceptionally high level. It may, therefore, be inferred that very little aphid movement normally takes place during this period.

The results obtained in these experiments do not reflect the full extent of aphid spread that would occur under natural conditions. Normally aphids would move both across and along the rows from an infested source, but due to the design adopted in this experiment only the latter type of movement has been studied. In addition, the date of initial infestation was much later than would occur naturally, when nymphs would normally be deposited by alatae during May and June. Not only would the earliest of these aphids have the benefit of an additional two months, when climatic conditions were most favourable for reproduction, in which to establish colonies, but many focal points of primary infestation would be established by progeny of the alatae. Nevertheless, even under the restricted conditions of these experiments, aphids were present on 29% of the plants by 22nd November 1956 and on 39% by the following April.

Summary

Following artificial infestation with apterae and nymphs in July, the spread of aphids from a central point along the rows of narrow plots of strawberries was studied in 1955 and 1956. Due to plant to plant spread aphids had, by November in each year, reached a distance of approximately 15 ft on either side of the original point of infestation, but very little further movement occurred between November and April. It is suggested that much of the spread originated from aphids leaving maturing leaves as these became less palatable.

Acknowledgement

My thanks are due to Mr. D. K. Brown for his help in recording these trials.

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A NOTE ON THE KNOCK-DOWN METHOD FOR ESTIMATING NUMBERS OF INSECT PREDATORS ON FRUIT TREES

By R. C. MUIR and R. G. GAMBRILL

The knock-down method of estimating the number of insects on fruit trees involves killing the insects either by surrounding the tree with a vertical screen and releasing a mist of insecticide (1), or by completely covering the tree and applying an insecticide in the form of a fumigant or as an aerosol. In both cases the dead insects fall on to groundsheets placed beneath the tree. The technique, although laborious, provides an absolute check on indirect means of determining insect numbers. The method of enclosing the whole tree with a sheet has been used periodically, but the results obtained appeared to underestimate the populations. It was decided, therefore, to test the accuracy of the method by releasing a known number of marked insects on to a tented tree and counting the number recovered.

Materials

The groundsheet

The groundsheet consisted of six segments of ' Sisalkraft ' paper, each in the form of an equilateral triangle with sides 7 ft 6 in. in length attached to wooden battens. Following the practice of the orchard workers in Nova Scotia, each frame was hinged at the apex and halfway along the base so that each segment could be partially folded and the insects swept towards the apex into a suitable container (Fig. 1). An ordinary household hand-brush with soft bristles was used for this purpose.

Covering the tree

The task of covering the trees, which did not exceed 6 ft in height, was relatively simple. A rectangular cotton sheet was first folded in pleats parallel to one edge, which was secured to a heavy pole to prevent it from rising. The corners of the opposite, or upper, edge were tied to the ends of aluminium poles with which two men could lift the sheet over the tree (Fig. 2). It was found advantageous to throw the sheet into the breeze, and on windy days it was only possible to operate during lulls. When uncovering the tree, it was usually necessary only to raise the leading edge of the sheet with the poles and allow the wind to lift it off.

The insecticide

An extract containing 25% by weight of pyrethrins was used. Laboratory tests indicated that 0·5 g of extract per 1,000 cu ft would be sufficient to effect knock-down of the insects, but this was increased to 4 g per 1,000 cu ft to ensure satisfactory results under field conditions. The volume of the tented tree was estimated at not more than 500 cu ft so that 2 g of extract was necessary ; to achieve uniform distribution within the enclosed volume, this was made up to 150 ml with low-boiling-point (60-80° C.) petroleum spirit and applied with a ' Sparklet Aerosol Projector '.

The marked insects

Adults of *Blepharidopterus angulatus* (Fall.) were obtained from another plot of trees on the day before the determination, placed in 3 × 1 in. tubes and marked in the laboratory (2). Nymphs were not present in sufficient numbers to make it worthwhile marking them. A leaf and a few laboratory-reared aphids were provided for food, and the insects kept in the laboratory until the following day.

Procedure

The groundsheet was laid beneath the tree, with its segments closely fitted together, and the tree was then covered, the sheet being tucked under the outer edge of the groundsheet. About 20-25 of the marked *B. angulatus* adults were then released by entering the tent and placing the insects on to individual leaves. The marked insects were allowed a few minutes to settle before applying the insecticide and 15 minutes were allowed for it to take effect. Before uncovering the tree, the tent was entered, and the branches and sides of the tent were tapped to dislodge any insects. The segments of the groundsheet were then carefully folded to prevent loss of the catch during the removal of the sheet, after which the catch was brushed into a container for identification and counting. It was found that two operators could deal with a tree in about an hour.

The efficiency of the knock-down method

Population determinations were made on 29th July, 12th August and 19th August 1959. The efficiency of the method can be gauged by comparing the number of marked specimens recovered with the number released. With two exceptions (Trees 1 and 2) the efficiency of the method varied between 47·8 and 77·3% with an average of 59·5%. There appeared to be a slight improvement in efficiency for the Worcester Pearmain trees, but this proved to be not significant at the 5% level. The low efficiency may be due to the dead insects getting tangled in the foliage and twigs of the tree, for it has been frequently observed that dead *B. angulatus* and other capsids cling to rough surfaces such as the underside of leaves and the cloth of a beating-tray by the tangling of their fine tarsal claws in the surface. The unusually high rate of recovery obtained from Tree 1 is inexplicable, but immediately afterwards there was a light shower of rain, and the exceptionally low percentage recovery for Tree 2 was probably due to many dead insects adhering to the wet foliage. Tree 3, treated after the foliage had dried, gave a higher recovery rate comparable with that obtained from subsequent trees.

Comparison of numbers of *B. angulatus* on the varieties Worcester Pearmain and Cox's Orange Pippin

Since the method provides an absolute measure of the percentage efficiency of recovery of marked insects from each tree, it follows that the total number of adult insects on the tree can be calculated from the number of unmarked insects collected.

It will be apparent from the Table that the totals of unmarked insects collected from the Worcester trees were higher than those from Cox. To compensate for differences in tree size, all branches and twigs of 3 in. and over were measured, and the estimated population expressed as numbers per 100 in. of wood. The Worcester trees carried a higher density of *B. angulatus* than those of Cox, the averages on 12th and 19th August being 4·7 and 6·5 respectively on Worcester and only 2·2 and 1·2 on Cox.

The reason for this higher density on Worcester is not fully understood, but one important factor

TABLE

NUMBERS OF ADULT *B. angulatus* OBTAINED BY THE KNOCK-DOWN METHOD SHOWING EFFICIENCY FOR EACH TREE AND ESTIMATED TOTALS

Date	Tree no. and variety	No. released	No. recovered	Efficiency %	No. unmarked recovered	Estimated total unmarked	Average per 100 in. branch
29th July	1 Cox	26	25	96·1	12	12·5	1·2
	2 ,,	28	9	32·1	8	24·9	2·9
	3 ,,	28	14	50·0	12	24·0	2·7
12th August	4 ,,	21	13	61·9	15	24·2	3·0
	5 ,,	23	11	47·8	9	18·8	2·2
	6 ,,	22	12	54·5	8	14·7	1·5
	7 Worcester	24	16	66·7	52	78·0	5·2
	8 ,,	24	16	66·7	24	36·0	3·8
	9 ,,	24	12	50·0	26	52·0	5·1
19th August	10 Cox	18	9	50·0	4	8·0	1·7
	11 ,,	22	15	68·2	0	0	0
	12 ,,	24	12	50·0	8	16·0	2·1
	13 Worcester	22	16	72·7	36	49·5	4·9
	14 ,,	22	17	77·3	33	42·7	6·1
	15 ,,	18	9	50·0	28	56·0	8·5

Fig. 1
Collecting the catch after knock-down from a segment of the groundsheet

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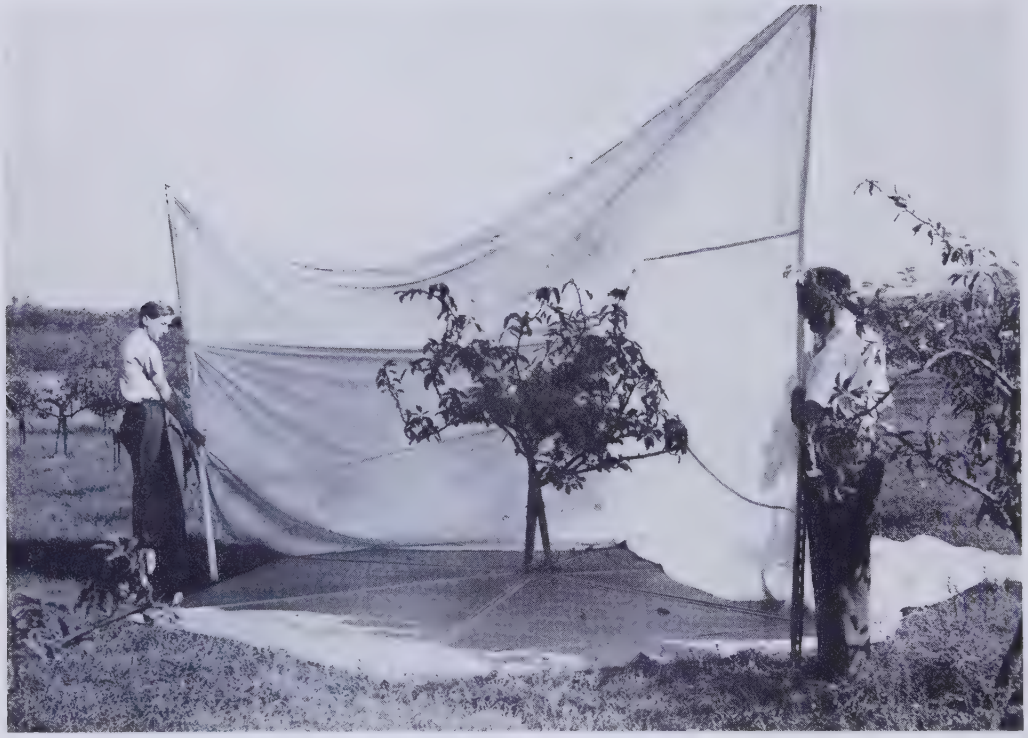

FIG. 2

Covering the tree prior to knock-down. Note the segments of the groundsheet

may be that the leaf density of the fruit tree red spider mite, *Metatetranychus ulmi* (Koch), an important source of food for *B. angulatus*, is often higher on Worcester than on Cox. The fact that the leaves remain on the tree longer on Worcester and so would carry a food supply longer is also important as many eggs are still being laid in the autumn. There may also be better sites for oviposition on Worcester than on Cox.

Summary

The knock-down method for estimating numbers of adult *B. angulatus* on fruit trees is described. Its efficiency, calculated from the recovery rate of a known number of marked insects released on to a tented tree just prior to treatment, varied between 48 and 77%. It was thus possible to estimate from the numbers of unmarked insects collected, the total number of insects on the tree at the time of knock-down. The estimated densities on the varieties Cox and Worcester are compared.

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PLANT PROTECTIVE CHEMISTRY

DAMAGE ON APPLE BY ARSENIC, COPPER AND MERCURY SPRAYS: A SEVEN YEAR STUDY

By A. H. M. KIRBY and MARGERY BENNETT

The results of phytotoxicity tests with a variety of chemicals mainly on trees of Worcester Pearmain on M.IX and on branches of established trees of Cox's Orange Pippin on M.XII, have been published (Kirby and Bennett, 1952). In 1949 leaf-scorch was recorded on Cox's Orange Pippin, but not on Worcester Pearmain, when 1% lime-sulphur was applied in conjunction with 0·2% lead or aluminium arsenate or zinc fluoroarsenate ; this damage did not occur in 1950 or 1951.

The phytotoxicity risk associated with mixtures of lime-sulphur and acid lead arsenate was recognized in the first decade of this century. Many investigators have studied the chemistry of interaction, and Hodgkiss, Frear and Worthley (1938) showed that the amount of soluble arsenic present increased with dilution of the lime-sulphur from 1 in 10 down to at least 1 in 200 (0·5%). Moore (1946) reported the occurrence in 1937 of severe damage in the form of ' dull-brown, scorched patches scattered irregularly over the leaves ' where trees of Cox's Orange Pippin on various rootstocks had been sprayed before blossom with 1% lime-sulphur plus 0·4% lead arsenate ; this damage was attributed to soluble arsenic released by the lime-sulphur which was unusually dilute for that time of season. This, together with the results mentioned, indicated that although damage could occur on Cox's Orange Pippin with lime-sulphur at 1%, this was not regular.

Taylor (1951), in trials involving seven post-blossom applications on the variety Sturmer in New Zealand, obtained severe leaf scorch and moderate fruit injury with lead arsenate alone at 0·5%, but the addition of hydrated lime usually reduced the damage, which became negligible when 0·5% lime-sulphur (15% w/w polysulphide sulphur) and 0·1% colloidal sulphur were also added. On the other hand, in one trial where the lime-sulphur rate was *increased* to 1%, he obtained rather greater damage. His laboratory experiments showed that 0·5% lime-sulphur increased soluble arsenic by 100-fold, that colloidal sulphur had no effect, and that 3% hydrated lime reduced the soluble arsenic to negligible levels even when the lime-sulphur was added. Addition of an ionic wetting agent had no influence on the amount of soluble arsenic but nevertheless increased russeting severely. No trees were sprayed with lime-sulphur without lead arsenate, and it is possible that the increased damage recorded when the concentration of fungicide was increased from 0·5 to 1% was due to the fungicide itself ; in that case, the discrepancy between Taylor's results and those of other workers disappears.

Experiments, 1952-58

In 1952, a new plot of young trees became available at East Malling for further phytotoxicity studies, and long-term trials were commenced with the varieties Cox's Orange Pippin, Worcester Pearmain, and Laxton's Superb, all on M.VII. In the first year, lime-sulphur was applied, as previously, at 1% with lead arsenate at 0·2%. As, however, 0·5% lime-sulphur seemed even more likely to release toxic quantities of soluble arsenic, treatments were included using this rate in combination with lead arsenate, zinc fluoroarsenate, or aluminium arsenate, all at 0·2%. In order to provide a picture of authentic arsenic damage, one treatment, in the first year only, consisted of sodium arsenate (0·1% As_2O_5) applied without a wetting agent.

At the same time the opportunity was taken to observe the effects of sprays based on other elements known to be phytotoxic under certain conditions. Copper was therefore included in the form of Bordeaux mixture at 4 : 6 : 100, and mercury in the form of phenylmercuric chloride at 0·005% as a 2·5% wettable powder. A wetting agent, dioctyl sodium sulphosuccinate at 0·005%, was added to the former in all years except the first.

Spray applications were made once only in each year, at about the fruitlet stage. Treatments were randomized in six blocks, so that each treatment was applied to one tree of each variety in each block.

The control treatment consisted of unsprayed trees in the first four years, but was changed to 0·5% lime-sulphur for the last three years in order to give a better basis for comparing the lime-sulphur/lead arsenate mixtures. In the first two years, sprays were applied with a small self-propelled

machine giving only 75-110 lb/sq. in. pressure, but in the remaining years larger machines giving 150-200 lb/sq. in. were used.

The sample of aluminium arsenate used was rather coarse, not much more than 80% passing a 60-mesh sieve. It gave trouble by blocking nozzles in the early years and it was not till a ball-mill had been purchased in 1955 that it was possible to overcome this difficulty ; after being ground in this, over half of the material passed a 120-mesh sieve.

Results

Effects on foliage

The application of sodium arsenate in 1952 caused scorch on all three varieties ; leaf-fall from the Cox's Orange Pippin and Worcester Pearmain trees continued for over three weeks and scorch could still be seen at the end of the season. However, the combination of lime-sulphur with lead or aluminium arsenate, or with zinc fluoroarsenate, failed to cause scorch in any season. The incidence of leaf-spotting and fall on Cox's Orange Pippin was greater in 1953 ($P < 0.001$) where lead arsenate was used than on the unsprayed controls, but not than on trees receiving the other two arsenates ; no significant differences were found in any other season. It is to be expected from the data given in Table I that any damage arising would be from the mixture of 0·5% lime-sulphur with lead arsenate in which the percentage of water soluble arsenic exceeds by about tenfold that in either of the other comparable mixtures. It would seem, therefore, that conditions are seldom favourable for such damage to occur even when the mixtures are applied at a stage of tree development usually reckoned to be most susceptible to spray damage. The absence of further release of soluble arsenic from zinc fluoroarsenate or aluminium arsenate on dilution of the lime-sulphur from 1·0 to 0·5% was unexpected and striking ; with lead arsenate the increase was as expected.

TABLE I

RELEASE OF WATER-SOLUBLE ARSENIC ON MIXING LIME-SULPHUR SOLUTIONS WITH THREE ARSENIC COMPOUNDS AT 0·2%

Lime sulphur %	Water-soluble arsenic present (as p.p.m. As_2O_5)				
	Lead arsenate	Zinc fluoroarsenate		Aluminium arsenate	
		1946 sample	1951 sample	Sample 1*	Sample 2†
1·0	96	9	16	19	18
0·75	122	10	13	13	19
0·50	204	10	16	16	26
None	4	1·8	1·1	19	3·3

* Commercial sample from interaction of $Na_3AsO_4 + Al_2(SO_4)_3$.
† Sample prepared from $Al(OH)_3$ and H_3AsO_4, to avoid occlusion of sodium arsenate.

No damage due to PMC occurred in 1952-54, but in 1955 all three varieties showed slight leaf-fall after a week or so, and Laxton's Superb developed chlorotic spotting later. That year (1955) was the only one in which spraying was followed by wet weather ; it was an exceptional season for organomercurial damage on pear also (Kirby and Bennett, 1958). In 1958, leaf-fall occurred on Cox's Orange Pippin where an organomercurial was applied, reaching a maximum within a fortnight.

The only consistent results were obtained with Bordeaux mixture, which caused necrotic spotting on all varieties in all years. This usually amounted to scorch on Cox's Orange Pippin, followed by leaf-fall for up to three weeks.

Effects on fruit

No losses due to reduced fruit-bud formation or to reduced fruit-set were found. Differences in the development of mature fruit, related to the fruit buds present in the spring, were found in most years. In 1952, sodium arsenate caused all the fruits of Cox's Orange Pippin to fall, whereas the other treatments had no effect significant at the 5% level ; the effect on Worcester Pearmain was not so marked and on Laxton's Superb was virtually non-existent. Bordeaux mixture and PMC were applied on an adjacent plot in that year and the results are not strictly comparable.

A significant reduction of mature fruit was caused by Bordeaux mixture on Cox's Orange Pi in three years, and on Worcester Pearmain in 1957 (Table II). The losses were smaller on t varieties in the remaining years, and were not significant in any year on Laxton's Superb.

TABLE II

MATURE FRUITS (AUGUST) AS PERCENTAGE OF FRUIT-BUDS

Year	Cox's Orange Pippin			Worcester Pearmain		
	Bordeaux mixture	Control*	P level	Bordeaux mixture	Control	P level
1953	2·7	29·9	<0·1%	—	—	—
1954	18·9	51·9	<1%	—	—	—
1957	60·8†	80·1†	>5%	59·9†	81·2†	<0·1%
1958	16·6	49·6	<0·1%	7·6	21·7	>5%

* Unsprayed in 1953 and 1954; 0·5% lime-sulphur in 1957 and 1958.
† Calculated as percentage of fruit set.

The mixture of 0·5% lime-sulphur and 0·2% lead arsenate caused a reduction of mature f (P <0·001) on Cox's Orange Pippin in 1953 only, and not in the subsequent five years when the t were more mature. The mixtures of 0·5% lime-sulphur with zinc fluoroarsenate or aluminium ar ate appeared to produce a reduction (P <0·05) in 1956, but not in any other year. As no reduct were found on the other two varieties, it is clear that none of these mixtures is likely to affect t varieties seriously ; this is also borne out by the absence of significant losses at harvest.

No reductions in harvested crop were detected for Laxton's Superb. Bordeaux mixture ca reduction in both number and weight of crop on Cox's Orange Pippin and Worcester Pearmai 1957 and 1958 (Table III). The only other significant loss was caused by PMC on Cox's Orange Pi in 1958.

TABLE III

REDUCTIONS IN PICKED CROP DUE TO BORDEAUX MIXTURE

Year		Cox's Orange Pippin			Worcester Pearmain		
		Bordeaux mixture	Lime-sulphur 0·5%	P level	Bordeaux mixture	Lime-sulphur 0·5%	P lev
1957	Number	16·8	60·5	<0·1%	55·7	78·2	<5%
	Wt (lb)	4·0	14·6	<0·1%	10·8	15·2	<5%
1958	Number	46·2	128·5	<0·1%	18·5	45·8	≏5%
	Wt (lb)	7·0	19·8	<0·1%	2·9	9·7	<5%

Although Laxton's Superb cropping was unaffected by any treatment, severe russeting o fruit by Bordeaux mixture was evident in 1953 and the remaining years that this variety was t This treatment also markedly increased russeting, especially of the side of the fruit, in all year the other two varieties (Table IV).

The only occasion that an arsenate seemed to be associated with increased russet was on C Orange Pippin in 1956 with 0·5% lime-sulphur and 0·2% zinc fluoroarsenate ; this increase slight compared with that caused by Bordeaux mixture in the same trial. PMC caused some e russeting (P <0·001) on Cox's Orange Pippin, but only in 1958.

Weather conditions

Consideration of the weather records for the period in each year following application o sprays (given in previous Annual Reports), leads to the conclusion that weather had very little nexion with damage from weak lime-sulphur plus lead arsenate, which has only appeared twi ten years in the present authors' experience. The anomalous result obtained in 1956 with the

TABLE IV

PERCENTAGE OF FRUIT RUSSETED BY BORDEAUX MIXTURE

Year	Site	Cox's Orange Pippin		Worcester Pearmain		Laxton's Superb	
		Bordeaux mixture	Control*	Bordeaux mixture	Control*	Bordeaux mixture	Control*
1953	Total	58·6	15·5	41·9	1·7	97·3	24·4
1954	Total	68·4	23·1	53·3	6·2	83·8	13·6
1955	Side	88·4	10·9	100·0	17·9	88·4	2·9
	Stalk-end	82·0	42·7	97·4	71·4†	71·4	22·8
1956	Side	99·9	28·4	52·2	1·4	97·2	17·5
	Stalk-end			63·9	33·1		
1957	Total	99·1	62·8	79·8	47·5	—	—
1958	Side	95·3	23·8	26·1	4·7	—	—

* Unsprayed: 1953-55; 0·5% lime-sulphur: 1956-58.
† All differences were significant at $P < 0.001$, except this one which was not suitable for analysis.

two forms of arsenate requires confirmation before it can be accepted. Weather conditions need not be invoked to explain the consistent effects of Bordeaux mixture, and the damage caused by PMC in 1955 and 1958 was associated with wet weather following spraying in both years.

Summary

Trees of Cox's Orange Pippin and Worcester Pearmain were treated in 1952-58, and of Laxton's Superb in 1952-56, with mixtures of 0·5% lime-sulphur and 0·2% lead arsenate, zinc fluoroarsenate or aluminium arsenate, with 0·005% phenylmercuric chloride (PMC), or with 4 : 6 : 100 Bordeaux mixture. Sodium arsenate, 0·1%, was also used in 1952 only.

The effect of sodium arsenate varied from almost total loss of fruit on Cox's Orange Pippin to no significant loss on Laxton's Superb, although all three varieties had badly scorched leaves. On the other hand, neither leaf nor fruit damage due to the arsenic mixtures was serious, being confined to lead arsenate in 1953 and to the other two mixtures in 1956. Weather conditions do not seem to have had any bearing on these results.

PMC at 0·005% caused some leaf spotting and fall in 1955 on all three varieties, and on Cox's Orange Pippin in 1958 when fruit loss and russeting was also caused ; in both years, wet weather followed spraying.

Consistent damage was caused by Bordeaux mixture at 4 : 6 : 100. Necrotic spotting of leaves and severe russeting of fruit was caused on all three varieties in all years, and loss of crop weight was usual on Cox's Orange Pippin and Worcester Pearmain, though not on Laxton's Superb.

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A RAPID METHOD OF MEASURING THE MAGNESIUM CONTENT OF LARGE NUMBERS OF INDIVIDUAL LEAVES

By M. ALLEN

To study factors involved in the uptake of magnesium from foliar sprays applied to apple tr it was found necessary to measure the magnesium content of large numbers of individual leave existing methods of analysis were not expeditious enough and a new method was devised. T is based on the Titan Yellow method of Young and Gill (1951) as modified by Mason (1952) a possesses the following novel features :

(1) Excess Titan Yellow, present after formation of the red absorption complex with magnesiu is removed by treatment with an alkaline solution of potassium ferrocyanide and potassium fe cyanide ; blank solutions can then be brought to zero on the absorptiometer and the most sensit part of the (logarithmic) scale used. If excess dye is not removed, the blank solution cannot brought to zero, and a much less satisfactory part of the absorptiometer scale must be used.

(2) In the analysis only two solutions (apart from those containing the magnesium) are us so that the method is rapid and can deal with large numbers of samples. Thus determinations o gross of magnesium solutions are currently carried out within two hours by one assistant.

Method

Reagents

Titan Yellow.—Dissolve 6 g of boric acid and 0·3 g of Titan Yellow (Hopkins and Willia 9279) in water, add 10 ml of 40% caustic soda solution and make up to 2½ l ; keep in a well-stoppe bottle. (Using Titan Yellow from another source, it was found that almost twice the quantity h to be used to give satisfactory results.)

Polyvinyl alcohol.—Dissolve 10 g of vinyl alcohol (polymerized) in 500 ml of water. No spec precautions need be taken for keeping this solution which can be used for up to three weeks.

Mixed reagent.—This should be made up daily as required by mixing 5 volumes of Titan Yell solution with 1 volume of polyvinyl alcohol solution and diluting to 20 volumes with water. I kept in a bottle fitted with a soda-lime tube and dispensed out of contact with air.

Alkaline ferricyanide solution.—Mix together 50 ml of 12% potassium ferricyanide soluti 50 ml of 8% potassium ferrocyanide solution and 15 ml of 40% caustic soda solution ; make up 200 ml with water. This solution should be made up daily as required.

Nitric acid solution.—A 0·03N solution to which has been added 2½ ml of 70% hydrated calci nitrate per litre.

Procedure

Leaves are dried, weighed, and ashed in 3 × 1 in. glass specimen tubes as already described Allen and Llewelyn (1954). On removal from the furnace the tubes are allowed to cool to ro temperature and 20 ml of nitric acid is added to each tube. The tubes are held in rows of six in bo each of which contains half a gross of tubes ; two boxes at a time are put on a shaker for 40 minu after which a suitable aliquot of the acid solution is taken from each tube and introduced into a 5 by ½-in. test tube. The test tubes are also arranged in rows of six in blocks, each of which conta half a gross of tubes. A further test tube is now added at the end of alternate rows, and to each these tubes an aliquot of nitric acid is added ; the contents of these tubes will act as blanks in determination. An extra set of six tubes, each containing an aliquot of nitric acid to which a kn amount of magnesium has been added, is also provided to furnish a calibration curve ; there thus 162 tubes in all. Each tube is taken in order, 5 ml of mixed reagent is added, the content the tube are shaken, and 1 ml of alkaline ferricyanide solution is added ; the contents of the t are then shaken once more. After this the tubes are left for 40 minutes, by which time change intensity of colour due to formation of the complex or bleaching of the excess Titan Yellow are occurr at a negligible rate. The depth of colour is measured with a Hilger H810 ' Biochem ' Absorptiom with a Kodak 52 filter (maximum absorption 520 mμ), the instrument being set at zero for each the blank solutions in turn. In practice the rate at which the colour intensity is measured is the sa as the rate at which mixed reagent and alkaline ferricyanide are added to the tubes, and only v small adjustments to the instrument have to be made throughout a series of readings becaus changes in the blank solutions. The calibration graph is a straight line passing through the or

and covering the range 0-18 μg of magnesium in the aliquot taken, and 0 to 0·7 on the absorptiometer scale ; above this point the intensity of colour is not proportional to the amount of magnesium added, and readings which occur in this region must be repeated, using a smaller aliquot of acid solution.

Precision

A number of samples of apple leaves, previously analysed for magnesium by Hunter's (1950) method, were obtained from the Plant Analysis Section of this Station. These were dried overnight at 80° C and, after cooling, 0·2 g lots of each sample were weighed individually into 3 × 1 in. specimen tubes and ashed ; it was found convenient to dissolve each lot of ash in 25 ml of nitric acid. Three separate analyses were carried out on these solutions, the results of which, together with those provided by the Plant Analysis Section, are given in Table I. For determination A, a 0·5 ml aliquot of acid

TABLE I

MAGNESIUM CONTENT OF DRY LEAF MATERIAL EXPRESSED AS A PERCENTAGE

Determination	Leaf sample number									
	1	2	3	4	5	6	7	8	9	10
A	0·25	0·17	0·10	0·14	0·12	0·13	0·22	0·20	0·08	0·07
B	0·25	0·18	0·12	0·15	0·13	0·13	0·22	0·20	0·09	0·08
C	0·25	0·18	0·11	0·15	0·12	0·13	0·22	0·20	0·09	0·08
Plant Anal. Sect.	0·27	0·18	0·10	0·13	0·12	0·15	0·20	0·21	0·11	0·08

solution was used ; for determinations B and C a 1·0 ml aliquot ; determinations A and B were carried out on the same day, and C two days later. It will be seen that reproducibility of the present method is good, and that agreement with results obtained by Hunter's method is satisfactory.

Acknowledgement

The author is indebted to Mr. A. B. Whitfield of the Plant Analysis Section for providing analysed samples of apple leaves.

Summary

A rapid Titan Yellow method for the estimation of magnesium in large numbers of single leaf samples is described ; 144 determinations can be carried out within two hours by one assistant.

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Part IV

BULLETINS FOR FRUIT GROWERS

FRUIT GROWING IN AUSTRALIA AND NEW ZEALAND
SOME IMPRESSIONS GAINED DURING A STUDY TOUR IN 1959

By W. S. ROGERS

The purpose of the tour was to study orchard cultivation of fruit and the latest lines of resear on this subject in Australia and New Zealand. Three months (February–May) were spent in Austral including the main apple picking season, followed by a month (May–June) in New Zealand.

The climate of Australia and New Zealand varies from temperate to tropical, and in the fr areas, which are generally warmer than those of Britain, many kinds of fruit grow well. The sc vary greatly, some are excellent, but others are shallow, impervious or leached.

The fruit farms are mainly small, 10–20 acres, and most of the labour is provided by the own and his family, with help at picking time. The fruit areas have the great advantage of abunda sunshine, and the disadvantage of great distances from the export markets where much of the fr is sold.

The 1957 fruit acreage of Australia, in 1,000's of acres, was as follows : apples 82, pears plums 11, cherries 5, small fruits 2, peaches 57, vines (mainly sultanas) 35, citrus 57, pineappl bananas, etc. 42. New Zealand has about 16,500 acres of fruit altogether. The area of pome fru is not changing much. The main apple varieties include Jonathan, Sturmer Pippin, Granny Smi Delicious and Cox's Orange Pippin ; and the pears include Williams' Bon Chrétien (Bartlett), Pa ham's Triumph, Winter Cole and Beurré Bosc. Strawberries, raspberries and other *Rubi* grow w in some areas, but the acreage is small, partly owing to shortage of labour.

Perhaps the most striking point was the high yield level of apples and pears in parts of New Zeala This, and factors to which it may be due, will be mentioned first, after which various cultural practi and matters of organization will be described.

Yields

Average yields of apples on the Australian mainland are about the same as in the U.K. Tasmania they are somewhat better, and in the main areas of New Zealand, much better. In Hawke's Bay area of N.Z. the official average yield of apples, including young trees, is 704 pack bushels per acre. This excellent result seems to be due to high sunshine, a long and warm grow season, sufficient rainfall, and a deep soil. The trees are planted rather closely (about 20 ft squa and trained fairly uprightly. The intense sunshine allows leaves to function well on a rather de tree, which has layer upon layer of fruiting units, like a ' factory ' with many productive ' storie The varieties and rootstocks used, and the method of pruning (see below) all take full advantage these features ; and good wind shelter belts aid the good climate.

This example, and the great productiveness of the irrigated Murray and Murrumbidgee vall (Fig. 1) in Australia (provided soil management is good) emphasize that the ' major elements ' plant growth, even more than N, P and K, are sunshine and water.

Rootstocks

In New Zealand, rootstocks M.XVI and M.XII and selected Northern Spy are largely used apples ; and in Australia, seedlings and Spy. Spy produces small, very fruitful trees, but they su from dieback and early degeneration, the causes of which are not understood ; M.XII succeeds wh Spy has failed, and it seems that the prolonged sunshine makes trees on M.XII more fruitful than England—even so, cropping is delayed. Pears are usually on pear seedlings, including the seedl race *Pyrus calleryana* D6 ; cherries, peaches and plums are all on seedlings.

The N.Z. Fruitgrowers' Federation nursery and the C.O.D. (Committee of Direction) nurs in Queensland are helping to secure the use of better rootstocks, and are now propagating apple tr on, for example, Merton 793 (resistant both to collar rot and woolly aphid) ; but the commer nursery trade has yet to be converted. There seems great scope for introduction and breeding

FIG. 1
Maps of Australia and (on larger scale) New Zealand, showing the main fruit areas.

rootstocks more suited to Australasian conditions ; for example, development of plum rootstocks for peaches, suitable for wet soil conditions, would be very valuable.

Pruning

Two interesting pruning practices that might be worth trial in England are (1) the de-fruiting of all leading branches back into 2- or 3-year wood, each year, to secure maximum growth, and (2) the ' multiple central leader ' tree form much used in the Hawke's Bay area (Figs. 2 and 3). From 3 to 5 main branches are trained nearly upright, in fact they are tied together at the top with a loop. These bear lateral branches with wide and strong crotch angles. Once the framework is established, pruning is more or less on a Renewal basis. The result is a tall cylinder bearing many layers of fruiting units. The frame is strong and the branches do not sweep the ground.

Soil management

The use of autumn and winter cover crops is common ; and permanent swards are also becoming popular, often in conjunction with irrigation. Subterranean clover, of which many strains are available, does well. An interesting way of preventing grass from smothering the clover, was to disc-up one alley in four each year. The partial cultivation of a permanent sward each spring, and then allowing it to re-establish, was also reported successful. The hybrid Italian ryegrass H1, which grows in winter, is popular as a cover crop in New Zealand and is apparently not too checking. Sheep are often grazed in the orchards, in winter ; their front teeth are sometimes cut, to prevent tree-barking.

Irrigation

The achievements of irrigation in turning a former desert into a fertile fruit belt in the Murray and Murrumbidgee plains, were impressive ; but it was disturbing to find that great problems have arisen from rising water tables and waterlogging. These come from applying very large amounts of water to a porous top soil with impervious subsoil. Irrigation by long furrows under such conditions leads to seepage near the furrow head. The risk is much less with sprinkler irrigation, which uses only about half the water.

The first line of attack on the problem has been to install drainage, to remove excess water. It would seem that greater efforts to ensure that excessive water is not applied are also required. Water deficits can now be calculated or measured, and irrigation planned only to meet this deficit.

There is a warning here for our own growers, who may use irrigation on flat areas with impervious subsoils. A wise precaution is to install ground water-level observation tubes.

Fruit thinning

Fruit thinning sprays, such as NAA plus glycerine, and naphthalene acetamide were found successful in some areas. The sprays are applied only to the tops of trees, and the operator adjusts the amount according to the amount of blossom on each tree.

Pests and diseases

Mites, codling moth, and scab are all present in Australasia, and good spray schedules are needed to obtain fruits suitable for export markets. Medium volume air-blast sprayers are commonly used. Woolly aphid is not a major problem now, although the root form is still troublesome occasionally. Collar rot (*Phytophthora cactorum*) causes losses in New Zealand, and high working on resistant rootstocks is recommended. Fire blight has been present for many years in New Zealand, but is seldom really troublesome ; young infected shoots are usually cut out, but older infections are often found to heal from underneath. Some virus diseases, such as apple mosaic, are widespread, and work to eradicate them has now begun. Strawberry viruses are present to some extent. Raspberry viruses are not a serious problem in Tasmania and New Zealand, for the major vector *Amphorophora rubi* is absent. A Red Antwerp raspberry plantation that had remained healthy for 40 years was seen near Hobart.

Cherry cages

Cherry trees in New Zealand are usually enclosed in huge cages of wire netting on a framework of poles and wires, to keep off the birds (Fig. 4). The trees, although on Mazzard seedlings, are less vigorous than those in Kent, and can be contained in a cage 17 ft high. The largest cage seen covered 5 acres. The cost of such cages is about £1,000 per acre, but the growers consider them well worth while

Fig. 2

Seven-year-old Jonathan on M.XXV, at the Havelock North Research Orchard of D.S.I.R., N.Z. Note the tie, keeping the main branches upright. Note also the tall windbreak in the background.

Fig. 3

Ten-year-old Rome Beauty, trained to 'multiple central leader' form, in Hawke's Bay area, New Zealand. This plantation bore 1,400 bushels per acre at 10 years old.

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FIG. 4
A wire netting cage protecting mature cherry trees from birds, in Alexandra, New Zealand.

FIG. 5
Bulk harvesting pears in Tasmania. Three of Mr. T. Francombe's bins on their special trailer. These bins can also be handled by fork lift or by overhead gantry.

Bulk harvesting

Bulk handling of apples and pears, involving the use of bins holding 25–30 bushels or trailers holding 90–100 bushels to bring the fruit from the orchard to the shed, is well established in New Zealand and Tasmania (Fig 5). The bins are handled with tractor fork lift attachments, and special hoists in the packing sheds. Although equipment costs are high, the users are convinced that the system pays well. Pickers like it, for it saves lifting bushel boxes. For farms handling up to about 20,000 bushels a year, bins are favoured ; for over 20,000 bushels, trailers are used. It is important to avoid sharp edges and to limit depth of fruit to about 20–22 inches.

Cold stores

Several large cold stores in New Zealand use reflective multi-layer aluminium foil insulation, which has reduced construction costs by nearly 50%. Results are as good as those with cork-insulated stores. This new method seems worth considering over here ; further details are available.

Organization and marketing

The New Zealand Fruitgrowers' Federation is a very successful co-operative organization, to which all growers of over 1 acre of fruit in New Zealand belong. It trades in sprays, fertilizers, machinery, etc., publishes a monthly magazine, runs a nursery, holds conferences, and collaborates with the statutory N.Z. Apple and Pear Marketing Board.

The N.Z. Apple and Pear Marketing Board markets all New Zealand apples and pears both at home and overseas (apart from limited roadside sales), and is in a powerful position to bargain for satisfactory prices. These two organizations have contributed greatly to the stability of the fruit industry.

Research Organizations

In Australia fruit research is carried out both by the Commonwealth Scientific and Industrial Research Organization and by the State Departments of Agriculture. In New Zealand the main fruit research is done by the Department of Scientific and Industrial Research, and some by the Department of Agriculture. Besides subjects already mentioned, research in progress includes work on blossom initiation, codling emergence, fruit development and storage, and on cell division. In the last instance, East Malling was able to contribute to the work, by providing a large consignment of tiny fruitlets.

This brief report can, of course, only touch on some of the main points of interest of this stimulating and instructive tour, in which many ideas were exchanged.

Acknowledgements

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I should like to express my grateful thanks to all these organizations, and also to many individuals who accompanied me on my visits or gave me information, and to many who also provided generous hospitality. Special thanks are due to Dr. F. R. Tubbs, Dr. O. H. Frankel of C.S.I.R.O., and Mr. J. D. Atkinson of D.S.I.R., New Zealand.

PRUNING TRIALS WITH DESSERT APPLES

By. A. P. PRESTON

Few cultural operations in the orchard affect the growth and cropping of apples so markedly as pruning. The selection of wide-angled branches to avoid branch breakage in future years, and the general shaping of the tree, are the main functions of pruning during the early years. Two tree shapes have been widely used by growers in recent years, the open-centre and the delayed open-centre. The question also arises, how best to prune the numerous laterals not needed for branch leaders. In this connexion the grower has a choice of three methods, established-spur pruning which aims at carrying the fruit on more or less permanent spur systems, renewal pruning in which the fruit is carried mainly on young wood, and regulated pruning, which involves removal of relatively little young wood.

These two tree shapes and three methods of pruning were compared in trials at East Malling, begun in 1945. Three varieties were selected, the regular bearing Worcester Pearmain, the biennial Laxton's Superb, and Cox's Orange Pippin. Some trees were grown on M.IV rootstock and others on M.II. The trials were planted on a loam soil (Malling Series) and on a loamy-sand (Lowlands Series merging into a gravelly phase of the Bearsted Series). Many of the Cox and Laxton trees on the sandy soil were severely stunted as a result of severe summer droughts, especially those in 1947 and 1949 ; trees of these varieties on this soil have, therefore, been omitted from the results described in this bulletin. The Worcester trees withstood the drought conditions well and, although they are somewhat smaller than those on the loam, they have made satisfactory orchard trees.

This bulletin is based largely upon the research papers on these trials published recently in the *Journal of Horticultural Science*. Fuller details of the tree shaping and pruning methods used may be found in Bulletin 133, ' Apples and Pears ', produced by the Ministry of Agriculture. A practical description of the regulated method of pruning was published in the Annual Report for 1953. A glossary of terms used in pruning fruit trees has been published by the Horticultural Education Association and copies may be obtained from Gibbs and Sons, Canterbury, Kent.

Tree shaping

All trees were planted as maidens in December 1945. The regulated treatment, though considered here as a pruning method, may also be compared, under shaping, with the open-centre and delayed open-centre trees as a ' natural habit ' shape.

Open-centre.—The trees were headed back to 30 in. at planting and feathers were removed. Primary branches were limited to three, these having their leaders tipped to obtain a secondary branch framework. Leader tipping continued each year, suitably placed laterals being tipped to form branches to fill in the tree's framework. Inward growing shoots were removed, so building an open-centre shape.

Delayed open-centre.—The trees were headed back to 33 in. at planting and feathers were removed. Successive tiers of framework branches were secured around a central leader over a period of years. Each branch was treated as a single unit and was not allowed to fork. At 7 years, when the trees were 8–9 ft high, the central leader was cut back into 3-year-old wood to a framework branch.

Pruning methods

Established-spur pruning.—Leader tipping became lighter as the tree framework developed and eventually only replacement leaders were tipped. Strong laterals not required for new branches were cut out ; very weak ones were shortened to 3 in. to form induced spurs. Laterals of medium vigour, mainly on the outside of the tree, were left full length to fruit ; these were shortened back later to a spur or, if they were becoming crowded or too large, removed altogether. Laterals from spur systems and induced spurs were shortened to 1 in. Dards and brindles on Worcester were left uncut.

Renewal pruning.—Leader tipping was light and was discontinued after the ninth year except on replacement leaders. About one-third of the 1-year laterals were cut back each year to 2–3 in. to provide more the following year, the remainder being left uncut. A proportion of 2-year laterals were shortened to 6 7 fruit buds each year, the remainder being left uncut to become 3-year laterals. Owing to vigorous growth during the early years, many 3-year laterals were left in for a further year before they were stubbed to produce more 1-year laterals.

Regulated pruning.—The trees were headed back to 30 in. at planting and feathers were removed. The number of primary branches was not restricted and during the next two years no more than three

leaders were tipped each year ; leader tipping then ceased. Laterals were neither spur-pruned nor shortened. Crowded, thin and weak laterals were removed irrespective of age, also those that competed with the unpruned leaders.

Effect of tree shape

There was no consistent difference between open-centre and delayed open-centre trees in growth and cropping with all three scion varieties. Considerable care was needed in forming the delayed open-centre trees to secure correctly spaced branches, and it was necessary to de-fruit the central leader while the tree's framework was being formed to avoid its becoming broken or misshapen under the weight of fruit.

Such branch breakage as occurred was fairly equally distributed between the open-centre, delayed open-centre, and regulated trees. Because the branches of delayed open-centre trees were not allowed to fork, no difficulty was experienced in getting pruning stools into the tree for fruit picking. Following a severe gale in August 1956, when the ground was already wet from heavy rains, some trees leaned or were blown over, but the number was small. Delayed open-centre trees on M.II appeared to be more stable than open-centre trees but there was little difference between the two shapes with trees on M.IV.

Shape of tree had no important effects upon fruit quality, setting or ' June ' drop.

Effect of pruning method

Tree size

During the early years regulated pruning made the largest trees and established-spur pruning the smallest with all three scion varieties. At fourteen years of age, however, the heavy cropping of the lightly-pruned trees had altered their shape and established-spur-pruned trees were generally taller, but rather less spreading, than either regulated or renewal-pruned trees.

Fruit set and ' June ' drop

With Cox, ' June ' drop occurred in most years and it was particularly severe in the eighth year when a heavy set of fruit had taken place (normally about 5%). The set and subsequent ' June ' drop was calculated per 100 blossoms. The figures showed that as the degree of pruning became harder, from regulated (very light), and renewal (light), to established-spur (medium), so the setting *and* ' June ' drop increased (Table I). The higher setting on established-spur-pruned trees was offset by the severe ' June ' drop in this season. These results were confirmed in later years.

Table I

Fruit set and ' June ' drop for Cox's Orange Pippin on M.II in 1952

Pruning method	Number of fruit buds	Per 100 blossoms			Number of picked fruits
		Set	June drop	Picked fruits	
Established-spur	170	23	20	3	27
Renewal	526	13	6	7	217
Regulated	908	11	4	7	381

Cropping

The most important effect of pruning method has been on cropping. The yield figures in bushels, separated into the establishment period up to 7 years of age, and the following 7 years are shown in Table II. The first crops were carried in the third year.

During the first 7 years regulated trees of Worcester on sand and loam soils yielded twice as much fruit as established-spur-pruned trees. At 14 years this order still held.

Renewal-pruned trees of Cox had borne twice as heavily, and regulated trees four times as heavily, as established-spur-pruned trees at 7 years. At 14 years renewal-pruned and regulated trees had still yielded more fruit than established-spur-pruned trees though the differences were less. Although the accumulated crop from renewal-pruned trees is still below that from regulated trees, since 1956 the annual crops from these trees have been almost the same.

With Superb also, a similar result on early cropping was found. At 14 years, however, established-spur-pruned trees on M.IV had yielded more fruit than regulated trees, whereas on M.II the crops from trees under these two treatments were nearly equal. Unlike regulated and renewal

TABLE II

TOTAL CROP IN BUSHELS PER TREE FOR TWO PERIODS

Variety	Rootstock	Period (years)	Pruning method		
			Established-spur	Renewal	Regulated
Cox's Orange Pippin	M.II	3–7	1	$2\frac{3}{4}$	$4\frac{1}{2}$
		8–14	$17\frac{1}{2}$	$19\frac{1}{4}$	19
		Total ..	$18\frac{1}{2}$	22	$23\frac{1}{2}$
Laxton's Superb	M.II	3–7	2	3	$3\frac{3}{4}$
		8–14	$21\frac{3}{4}$	$18\frac{1}{2}$	$19\frac{1}{2}$
		Total ..	$23\frac{3}{4}$	$21\frac{1}{2}$	$23\frac{1}{4}$
Laxton's Superb	M.IV	3–7	$2\frac{3}{4}$	—	$4\frac{1}{2}$
		8–14	21	—	$16\frac{1}{4}$
		Total ..	$23\frac{3}{4}$		$20\frac{3}{4}$
Worcester Pearmain (on loam) ..	M.IV	3–7	$1\frac{3}{4}$	—	4
		8–14	13	—	$21\frac{1}{2}$
		Total ..	$14\frac{3}{4}$		$25\frac{1}{2}$
Worcester Pearmain (on sand) ..	M.IV	3–7	1	—	$2\frac{1}{4}$
		8–14	$10\frac{1}{2}$	—	$13\frac{1}{2}$
		Total ..	$11\frac{1}{2}$		$15\frac{3}{4}$

pruning, established-spur pruning reduced the intensity of biennial bearing ; thus the smaller annual crops from these trees were probably more valuable than the heavier, biennial crops from renewal-pruned and regulated trees. Trees on M.IV were less biennial than those on M.II, but the trees on these two rootstocks were on different, though adjacent, plots so this difference may not be due solely to rootstock effect.

Fruit size and quality

All fruits were left unthinned. In the early years fruits from established-spur-pruned trees were rather large. With Superb, however, fruit size was consistently larger from established-spur-pruned trees than from those under other treatments. Regulated trees gave the smallest fruits, although in this respect there was often little difference between regulated and renewal-pruned trees. Thinning would undoubtedly have improved fruit size but would not have been necessary in most years with established-spur-pruned trees.

With Worcester also, fruits from regulated trees were rather smaller, on the average, than those from established-spur-pruned trees. Table III shows that this was so in 1958, a wet year, and 1959, a dry one. Again thinning would probably have improved fruit size, especially in 1959. During the years 1952-54, when the Worcester crop was graded, regulated trees carried a higher percentage of highly-coloured fruit than did established-spur-pruned trees.

TABLE III

FRUIT SIZE OF WORCESTER PEARMAIN IN 1958-59
NUMBER OF FRUITS PER POUND

	1958		1959	
	On loam	On sand	On loam	On sand
Established-spur ..	4·4	4·6	5·6	6·5
Regulated	5·8	5·1	7·3	7·7

In each of the years 1955-58 the Cox crop was commercially graded into five size grades, and two colour grades, Fancy (most red-coloured) and Choice (less red-coloured). The figures showed no

Fig. 1

Seven-year-old deblossomed trees of Cox's Orange Pippin on M.II after pruning and before carrying their first crop. Note effect of pruning on tree size. Established-spur-pruned (left); renewal-pruned (right); regulated (bottom).

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FIG. 2

Eleven-year-old trees of Cox's Orange Pippin on M.II after pruning. Delayed open centre, established-spur-pruned (top); open-centre, renewal-pruned (centre); regulated (bottom).

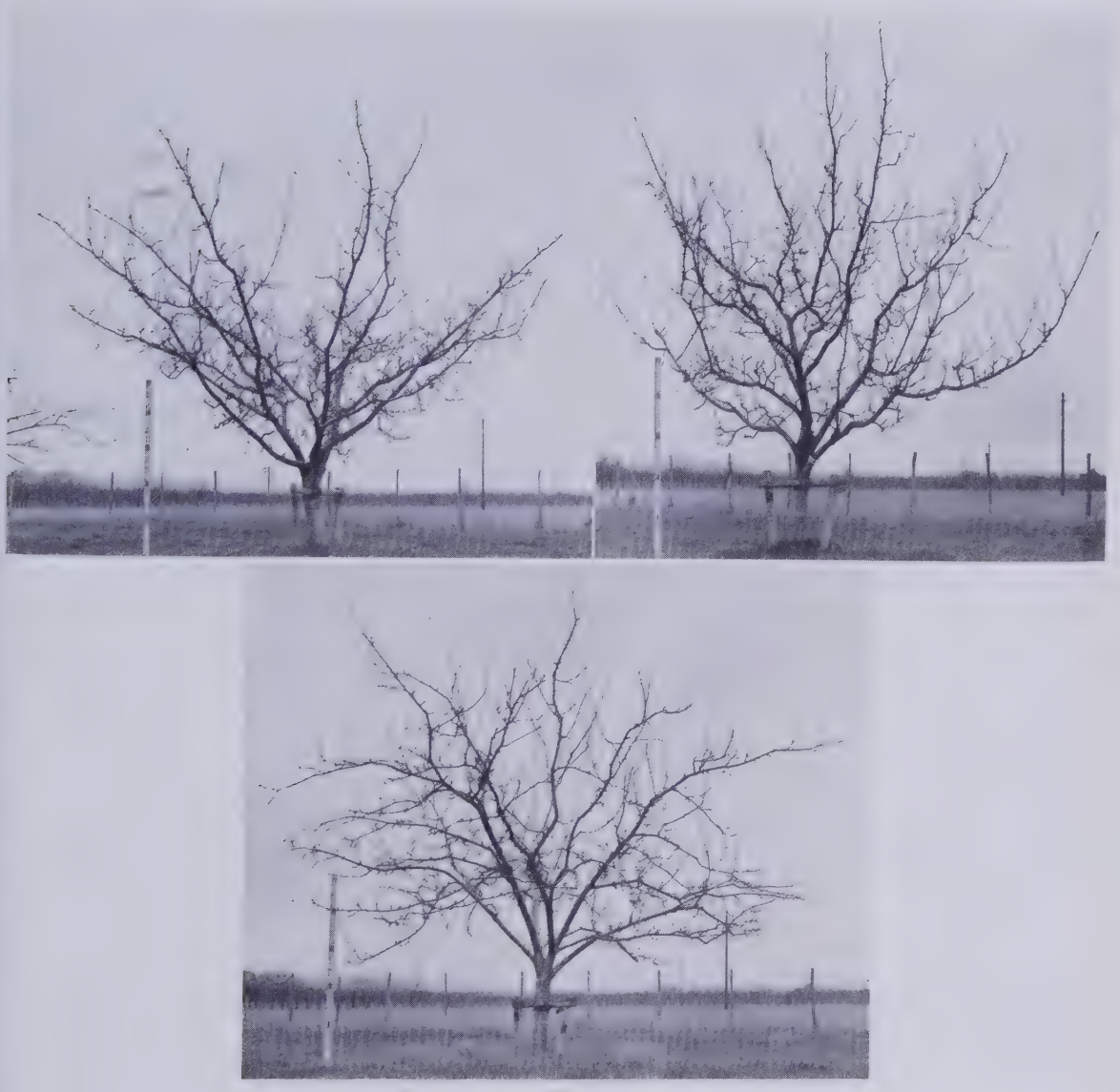

FIG. 3

Fourteen-year-old trees of Worcester Pearmain on M.IV before pruning. Open-centre, established-spur-pruned (left); delayed open-centre, established-spur-pruned (right); regulated (bottom).

appreciable effect of pruning method on the percentage of fruit in each grade (Table IV). There was also no difference between open-centre and delayed open-centre trees in these respects.

TABLE IV

FRUIT GRADING OF COX'S ORANGE PIPPIN, 1955-58. PERCENTAGE CROP IN SIZE AND QUALITY GRADES

	Established-spur	Renewal	Regulated
Quality grades			
Fancy	28	28	29
Choice	48	46	45
Culls*	24	26	26
Size grades			
2–2¼ in.	12	15	13
2¼–2½ in. ..	48	48	46
2½–2¾ in. ..	28	26	28
2¾–3 in.	10	8	10
3+	2	3	3

* Mainly russeted and poorly coloured fruit.

Hail damage

A severe hailstorm on 6th August 1956 damaged a heavy crop of fruit on Cox and Superb trees. After the fruit had been graded for size and quality, samples were graded for hail damage. With Cox, fruit from regulated trees was least damaged, and fruit from renewal-pruned trees was less damaged than that from established-spur-pruned trees. With Superb there was no significant difference between pruning treatments, although fruit from regulated trees was, on the average, least damaged.

Apple mildew

The incidence of apple mildew on Worcester and Superb trees was negligible. A succession of dry springs, the use of captan instead of lime-sulphur, and the omission of late winter spraying with DNC/petroleum were probably contributing factors in building up a severe outbreak of mildew on Cox in 1956. Renewal-pruned trees were slightly more affected than established-spur-pruned trees and regulated trees were intermediate. The differences were small. Rigorous cutting out of visible infections, together with a protective spray programme, enabled the disease to be brought under control by 1959.

Time taken to prune

In the thirteenth and fourteenth years the time taken to prune Cox trees by the three pruning methods was recorded. In the first year the amount of pruning was less than that required in the second, which followed a wet season. The mean pruning times per tree, averaged for these two seasons, are shown in Table V.

TABLE V

TIME TAKEN TO PRUNE A TREE; MEAN TIME AT 12 AND 13 YEARS FOR COX'S ORANGE PIPPIN ON M.II

	Regulated	Renewal	Established-spur
Minutes per tree ..	26	36	44

The *relative* times are the important ones since in this trial, with randomized treatments, the *actual* pruning times include moving the pruning stools from one tree to the next, which was often several trees farther down the row, also placing the prunings under each tree for weighing. Renewal pruning enabled a saving of 8 minutes per tree to be made over established-spur pruning. Regulated pruning afforded a further reduction in time, saving 10 minutes per tree over renewal pruning.

Effect of deblossoming trees in early years

As is common practice, all the trees in these trials were deblossomed the first year after planting. Some trees of Cox and Superb, however, were completely deblossomed for the first six years after planting; they included established-spur-pruned, renewal-pruned, and regulated trees. These deblossomed trees were then allowed to crop for the first time when 7 years old.

Tree size

The principal object in deblossoming was to demonstrate the effect of different pruning methods upon tree size without the interacting effect of cropping. Before cropping the relatively hard-pruned established-spur-pruned trees were the smallest and the lightly-pruned regulated trees were the largest; renewal-pruned trees were intermediate in size (Fig. 1). By the fourteenth year, after the trees had carried 7 crops, established-spur-pruned trees were the tallest but least spreading. The spreading regulated trees, and to a lesser extent the renewal-pruned trees, had to be 'set up' and have their more spreading branches cut back to keep them at their original spacing of 18 × 20 ft.

Cropping

The *first* crop from the formerly deblossomed regulated and renewal-pruned trees almost equalled the *accumulated* crop, at 7 years, from the normally treated trees receiving these pruning treatments; the first crop from established-spur-pruned trees of Cox was affected by a severe 'June' drop. This relatively heavy first crop did not induce irregular bearing with Cox, or with established-spur-pruned trees of Superb; but regulated and renewal-pruned trees of Superb became strongly biennial.

The subsequent crops from the formerly deblossomed regulated and renewal-pruned trees have been heavier than those from normally treated trees for both varieties, probably due to their larger size (Table VI).

Table VI

Total crop in bushels per tree from formerly deblossomed trees (7 crops) and normally treated trees (11 crops)

	Established-spur	Renewal	Regulated
Cox's Orange Pippin			
Formerly deblossomed ..	15	26	27
Normally treated ..	14	19	20
Difference	1	7	7
Laxton's Superb			
Formerly deblossomed ..	23	24	33
Normally treated ..	21	19	20
Difference	2	5	13

Practical considerations

With three scion varieties no special advantage has been gained in growing trees to the delayed open-centre shape rather than to the open-centre. In fact the performance of the regulated trees, where shaping received no special attention, suggests that the time and money spent on tree shaping may not always be justified.

Established-spur pruning, although a more rational method than the old rule-of-thumb spur pruning, was nevertheless too severe for all three varieties during the early years in these trials, and for Cox and Worcester throughout. Cox trees suffered from severe 'June' drop in some seasons and this was more with this pruning than with either of the other methods. Even on the poor sand Worcester yielded least fruit when established-spur-pruned. Undoubtedly there are conditions, for example, thin patches of soil in an orchard where new growth is scarce, where established-spur pruning might be justified in order to secure as much new shoot growth as possible—but these are often problem cases needing other cultural measures as well. The outstanding advantage from established-spur pruning in these trials has been with the biennial variety Laxton's Superb. Over the whole period these trees yielded at least as heavily as regulated and renewal-pruned trees and in some cases more so. Furthermore, they have been less biennial, due probably to the reduction

in number of fruit buds, and the stimulation of new shoot growth arising from the many small cuts made when pruning.

Renewal pruning has proved a more fruitful method of pruning than established-spur pruning. It is well suited to the growth habit of Cox. Considerable skill is required in the timely selection of replacement leaders and in securing a successional supply of new laterals along the branches. Three-year laterals, and 4-year ones where present, should be stubbed regularly to help keep up the supply of new laterals. If insufficient stubbing is done there is little or no growth response from the stubs. It is perhaps a more exacting method to apply than either established-spur or regulated pruning, but with mature trees of Cox it took less time to carry out than did established-spur pruning.

Regulated pruning has proved a highly efficient method for inducing Cox to bear early and heavily. Although in this method of pruning relatively little young wood is removed when compared with established-spur or renewal pruning, nevertheless the total weight of pruning wood removed was similar to that from trees under the other two methods. Fewer cuts were needed, however, since most of the pruning consisted of removing branches rather than shoots and leader tips. The method is simple and quick. Unskilled workers soon acquire judgement in removing wood once the basic principles are demonstrated, and the method lends itself readily to the use of pneumatic pruning tools. It is a useful method not only for filler trees, where early bearing is essential, but also for trees on vigorous and very vigorous rootstocks,* and, as these pruning trials have shown, for permanent orchard trees where growth and soil conditions are suitable. Under less favourable conditions it might be wiser to tip the leaders over a longer period, to use the renewal method or, under conditions of weaker growth, to use the established-spur method. Pruning is not, however, a panacea and other cultural measures are normally needed also under these conditions. The growth habit of Worcester makes it particularly suitable for regulated pruning under a wide range of soil conditions. Fruit setting is at present largely outside the growers' control and in heavy setting years some thinning of fruit may be necessary to ensure a higher percentage of crop in the larger size grades than was possible in these trials where thinning was purposely omitted ; but in most years established-spur-pruned trees, especially Superb, would probably not have needed thinning. Experience in the dry summer of 1959, however, showed that some trees under *all* three pruning methods would have benefited from thinning.

In assessing the relative value of the crops from trees under the different pruning methods, particularly those in the second 7-year period (Table II), account should be taken of the time needed to prune the trees (Table V). Assuming an orchard of 12- or 13-year-old uniformly-sized trees spaced at 17 ft square (150 trees/acre), a reduction of 10 minutes per tree in pruning time (e.g. regulated *v.* renewal pruning) would result in a saving of three working days per acre for one man.

Finally, another advantage from using light pruning methods, such as regulated and renewal pruning, is in their effect upon blossoming. Blossoms on 1-, 2-, and 3-year laterals open later than do those on older spur systems. As these lightly-pruned trees have more of this younger wood than established-spur-pruned trees, the chances of some of their blossoms meeting good pollination conditions, and of possibly escaping frost damage in some years, may be greater.

Summary

Results from bush apple pruning trials up to the fifteenth year, and including twelve cropping years, with Cox's Orange Pippin, Laxton's Superb, and Worcester Pearmain are described and the practical aspects are discussed from the grower's point of view.

* See *Rep. E. Malling Res. Sta. for 1958*, p. 47.

THE EFFICIENT FRUIT TREE

By D. H. MAGGS

The course of economic development is forcing fruit growers to develop more and more an industrial attitude to their methods of production. The orchard is becoming an apple factory and the fruit tree its production unit—an apple machine. To get optimal production, the machine must be of the size and type best suited to the methods of management and to the district, and must be run in the most efficient way. However, unlike the ordinary machine, which is made for the job and whose parts all have a known use, the apple tree is an organism only recently adapted to man's requirements, with habits and needs inherited from the past. We have very little idea of what makes it a tree, what determines its size and habit, what controls the relation between its parts (including the crop), how it reacts to sprays, and so on . . . and yet knowledge of this kind is essential if we are to make full use of its potentialities. The object of this bulletin is to describe how the apple machine—the fruit tree—is being taken to pieces to find out how it works, how its present performance is related to its working, and what may be the potential limits of what it will do. This, broadly speaking, is the programme of the Physiology Section at East Malling. It may seem rather a long-term objective, but it is as well to keep our ultimate goal in mind in case we find ourselves in strange country en route.

In general, the problem has been tackled by finding out how certain quantities change under various experimental treatments as the season advances, and from year to year. Sometimes the quantities are the weights of the main parts of the tree—leaves, stem, roots and crop—sometimes they are the weights of substances such as sugars and nitrogen in the various parts, or sometimes the concentration of growth substances, those compounds present as one molecule among many millions and yet profoundly affecting the behaviour of the tree. These investigations usually require from ten to fifty trees per treatment at each sampling, so that it can be seen that each experiment requires careful preparation if it is to be successful.

The outstanding feature of the growth of an organism is its ability to make itself, and this implies a delicate balance between all its parts. So it is difficult to start our analysis of growth by taking the most important part first, because there is no *most* important part. In this sense the crop is the least important part, because the crop cannot grow without the rest of the tree although the tree can grow without the crop until it is grubbed by an exasperated grower. To find out how this balance is established and maintained in the fruit tree we have to start with something simpler. The simplest trees that could be obtained in quantity were rooted shoots from the layer bed, and these had to be carefully chosen to get them all the same size. Experiments on these young trees are providing the ' signposts ' necessary to guide us to the meaning of the experiments on commercial fruit trees already in hand or planned for the near future.

The important pioneer work of the twenties and thirties has been confirmed, and it appears that the increment made by a young tree during a season's growth is divisible into two parts ; about a third goes into stem growth, the rest into leaves and root. Since the stem lies between leaves and root, we may picture it as a group of middlemen taking commission on the materials it passes to and fro ; in the wood, dilute solutions from the root, and in the bark, chiefly sugars made in the leaves. We do not yet know whether the middlemen take their commission on the basis of the number of them involved (i.e. the length of stem between leaf and root), or whether the percentage commission is fixed by law (i.e. by some internal control). The evidence suggests that leaf and root form smaller and smaller parts of the total increase in weight until the tree reaches a certain size and then their proportions remain constant. The picture would be of an expanding economy ultimately limited by the demands of its distribution system.

The stem fraction of the total increment is itself divisible into new shoots and increment of old stem, and the balance between these is determined by the degree of pruning. In one experiment it was found that

$$\frac{\text{New shoot weight}}{\text{Old stem increase}} = 0{\cdot}6 \times \frac{\text{Unpruned shoot length}}{\text{Pruned shoot length}} - 0{\cdot}3$$

and other experiments have given similar results for trees up to four years old. When we are able to estimate sufficiently accurately the increase in weight of a tree from, say, its increase in girth, we can test this result on mature trees. Before long we should have information which will enable us to divide up the old stem increment into the fractions going to each year's growth, and this may help to determine the most efficient tree form for a given type of orchard.

The amounts of leaf and root are similarly balanced. In our young trees towards the end of the season there is about twice as much leaf as there is root, but this ratio is influenced by many factors. These seem to act on the principle that the part that is being adversely affected tends to be increased so as to restore its overall production. Thus, when the trees are shaded the percentage of leaf increases, and similarly the percentage of root is increased following conditions of drought, low nutrition, and possibly high soil aeration. The working of this principle may be familiar to some growers who find that it is the weakest pieces of machinery that require the most spent on maintenance. So far we have looked at a few of the more obvious factors to see what kind of variation to expect, and have perforce ignored a large field of potentially useful information—the effect of sprays, pests, diseases, viruses, nutrition, and competition on the distribution of increment.

We thus have a picture of the young tree as two manufacturing concerns—the leaves and the roots—each using the other's products in their processes, and by the nature of their business forced to move continually away from each other and so maintain increasingly lengthy lines of communication. Clearly, without for uncommonly skilful management, one part would grow too fast for the rest and the whole organization become defunct. What is the nature of this management? It must be remembered that millions of cells are involved in each region and that a wide variety of substances are being produced—even in the stem regions some tissues play a positive part in the economy; we should not, therefore, expect to find one single mechanism of control, nor control at a single level of organization. In fact, to date, no specific control mechanism has yet been conclusively demonstrated. This is due to several circumstances. Firstly, the short time that the fruit tree, or any tree, has been studied from this aspect; secondly, the study of organization itself has scarcely reached the level where the kinds and minimum numbers of mechanisms possibly involved can be specified; and thirdly, the difficulties in isolating and testing the mechanisms. Certain indications have begun to emerge. Some control may be given by the relative levels of production from root and leaf, but some other mechanism is required to account for the rapid and sensitive responses that are experimentally observed. It is possible that such a mechanism will be found in the activities of various growth substances and the means by which they are built up, activated and broken down. Several of these substances have been isolated from stems of apple and plum, and their activity assessed by their effects on various parts of plants such as seedling leaves of wheat or oat, cress roots, bean leaves, etc. Some of the substances increase the growth rate of the tissues, others decrease it, while still others may be active in one test and inactive in another. If such substances produce similar effects within the fruit tree, they can be the agents of very specific growth control.

Already, work on the readjustments that occur in the shoot when the balance between the growth of leaves, internodes, and lateral buds is disturbed experimentally, has suggested the existence of two groups of growth regulators in the very young leaves of Crab C shoots; these control the elongation of the young stem and the expansion of the leaves. The well-known growth regulator IAA (β-indolylacetic acid) and its related compound IAN (β-indoleacetonitrile) have been isolated from certain plants, and substances probably allied to them have been found in fruit trees; these have so many effects, ranging from delaying fruit- and leaf-drop to increasing root respiration, that it is difficult to say what their main function is in the plant. Judging by what has been found in other plants, we may expect to find growth substances made in one part of the fruit tree and controlling vital processes in another part, or even two complementary substances produced in two different parts and effective in a third. Moreover, since the problem is essentially one of communication between the parts of the tree, it will not be surprising if there is some further, undiscovered, mechanism of control somewhere in one of the various communication channels within the tree.

This picture of control and counter-control that we have postulated to account for the relations between the major parts of the tree must be redrawn for the various kinds of cells within each part, the development and relative numbers of fibres, vessels, chlorophyll cells, root hairs, and so on. In organizations such as single cells or groups of cells, the distances involved are so small that the experimental effects depend largely upon the rates at which the various molecules pass from regions where they are concentrated to regions where they are dilute. The study of such rates can best be done when the environment is closely regulated, so that these experiments will have to be made with parts of plants or tissue cultures growing in artificial media. The information on the control of growth will, as it builds up, provide with increasing speed the 'know-how' and theory for practical field applications already foreshadowed in thinning and stop-drop sprays, maleic hydrazide, gibberellic acid, and so on. And beyond that, presumably lies the investigation of the control of controls . . . This is the stage where the identity of the plant may be altered; it can be permanently forced out of its normal pattern of behaviour and is no longer the same as it was. We have tunnelled through our problem and come face to face with the Plant Breeder, who must be considered an occupational hazard by the Plant Physiologist.

So far we have discussed the relation between parts of the fruit tree. What of the quantity of

growth, the amount of growth made in a single season or the ultimate size of the tree? Up to the present we have not got much further than putting on a numerical basis generalizations long known to fruit growers and nurserymen—that one variety makes a bigger tree than another. The solution of this problem is the key to the solution of the problem of the mechanism of rootstock effect. In fact our experiments on the rootstock effect have contributed to our ideas on tree growth. It has been found that if the growth rate of the shoot under special conditions is very fast it does not follow that the root system will grow fast too. A high potential shoot growth rate does not mean a high potential root growth rate. The shoot system of one variety may be capable of very rapid growth and its root system of only slow growth, while the reverse, low potential shoot rate, high potential root rate, may hold for another variety. Because the one variety will be limited by the growth rate of its root system and the other by the growth rate of its shoot system, on their own roots they may both grow into trees of the same size. This has been shown to be the case for Warwickshire Drooper and Victoria Plum. This indicates that both root system and shoot system make their own specific contribution to the growth rate of the complete tree ; the indirect evidence of stock/stock experiments confirms this. The rootstock effect is obviously mainly due to the growth potential of the root system and we know nothing of the factors determining this, apart from what we can judge from the growth of established trees on different soil types, and with different manurial programmes. For the shoot system it is known that the rate at which it starts growing in the spring and the length of time that it grows are both important components of its total growth, but obviously this is nowhere near the whole story. The number of shoots that grow out from the leader is another important character ; each additional shoot produces a definite amount of increment—so that the effect of pruning is not to divide a fixed amount of growth among a few shoots instead of many, though it may reduce the water requirements and so delay the effects of water shortage. Since varieties differ in the number of shoots they produce, this will have repercussions on the form of the tree and its rate of growth.

Although all the parts of the tree interact in a balanced equilibrium, the total increment is in the first place built up in the leaves through the action of light in enabling atmospheric carbon dioxide to be built into organic substances. According to circumstances the same amount of foliage can produce increment at different rates. The increment on a fast-growing tree is greater than the increment produced by the same amount of foliage in the same time on a slow-growing tree, whether it is on the same or on a different rootstock. Spur leaves may have a lower rate of production than shoot leaves, while a crop may speed up the rate. Indeed, investigations on single leaves have shown sharp fluctuations in the carbon dioxide uptake of a single leaf and very interesting patterns of air-flow over them. The extension of this work to the effects of various horticultural practices may be expected to have considerable practical repercussions. Since shading reduces the activity of the foliage, cultural methods which keep the tree open, or, as with light pruning and heavy cropping, open it up as the season advances, will increase the efficiency of the foliage.

Although spray materials are in theory selectively toxic towards their victims, their effects on the fruit tree are greater than is sometimes apparent. Some reduce the efficiency of the foliage without visible damage, while the visible damage caused by others varies in severity according to the time of year ; e.g. foliage is much less susceptible in May to some sprays than in July. Moreover, the ability of a tree to recover from spray damage varies with its general growth rate. The information gained from leaves is being used to guide experiments on the fruits themselves which are so much more expensive than leaves to use.

It has been emphasized that no one part of the tree functions independently of the others and that ultimately all parts of the tree are dependent for supplies on the activity of the leaves. Among the primary products of leaf activity are carbohydrates (sugars, starch, etc.) ; these have a three-fold importance in the life of the tree by providing fuel which is used during maintenance and in the manufacture of new products, by providing the building bricks for new cell-wall materials, and by providing ' skeleton ' molecules which may be re-built into the living protoplasm of the tree. A study is being made of the carbohydrate resources of the fruit tree in an attempt to define the nature and the function of these substances in relation to the various aspects of growth. Carbohydrates are used up during growth, but at times when the supply from the leaves exceeds the demand they are stored in the living cells throughout the tree. Attempts are being made to assess the value of such stored materials and to find means by which their use may be controlled most efficiently towards the improvement of orchard economy.

So far in this discussion, there has been no mention of the one thing of most interest to growers—the crop. The reason for the omission is not lack of awareness of its importance, but, as may have become apparent, the complexity of the systems and the lack of suitable experimental material. One effect of extreme cropping has been known from pomological studies of biennial bearing—that it reduces growth ; but it is not certain that more moderate crops have a similar, if diminished, effect.

Now that an approximate pattern of vegetative growth has been established, the same techniques are being applied to fruiting trees, and we may hope before long to know what the effects of various degrees of cropping are on the growth of the various parts of the tree, and what may be the functions of reserves in the production of the crop.

In preparing this bulletin, the author's original aim was to explain to growers the results and, especially, the purpose of his experiments to analyse the growth of young trees. Inevitably, the work of his colleagues came to occupy such large portions of the picture that this is virtually a joint bulletin. Some of their justifiable criticisms have been over-ridden to avoid too many ' ifs ' and ' buts '. In particular, I must confess to an over-indulgence in painting a brave new physiologist's world where sweet reason reigns supreme. Growers who have persevered this far must several times have felt that they had ' heard that one before '. Nevertheless, the author and some of his colleagues believe that these things are possible, and that it is their job to prove it ; in many cases the physiologist's findings only reach the grower after testing by the pomologists to find their best applications in orchard practice.

PROGRESS IN RESEARCH ON *VERTICILLIUM* WILT AND VIRUS DISEASES OF HOPS IN 1959

By R. V. HARRIS

This is the annual review for 1959 of items of special interest to hop growers in the general Research Report of the Plant Pathology Section (see p. 23).

Verticillium wilt

Research on tolerant varieties

The results of the final Institute of Brewing trials with Janus (1957 crop) were encouraging

Of the three new tolerant varieties, Density, Defender and Janus, fully reported on last year and now released to the commercial propagators following large-scale farm and brewing trials, Janus was the last to complete such trials, and the results of its final brewing trials thus only became available this year. In these Janus proved acceptable to all the breweries involved at not less than 25% replacement of Fuggle in the normal grist, to over half the breweries at 50%, and to two breweries at 100%. This will interest growers with wilt who are looking out for a new tolerant variety with a reasonable prospect of proving an acceptable substitute for Fuggle in copper hopping.

Although from our present comparatively limited cultural information Janus seems to be only a very moderate cropper, more extensive planting when health-tested sets begin to become generally available from the propagators, i.e. in autumn 1960, may show an up-grade in this respect. Moreover, its cropping could most probably be improved by closer planting or by other cultural modifications.

The Wye-East Malling joint breeding of new tolerant varieties is reaching its final stages

Arrangements were concluded during the year for the establishment of large-scale farm trials of three short-listed seedlings for cultural quality combined with wilt tolerance. For further details readers are referred to the Report of The Hop Research Department, Wye College for 1958.

The situation on those farms where tolerant varieties have hitherto severely wilted took a distinct turn for the better in dry 1959

Of two possible alternative explanations of the exceptional outbreaks mentioned last year, the most disturbing was the possibility that a yet more ' progressive ' strain of the wilt fungus may be on the way. It is therefore pleasant to be able to report that the records in the dry season of 1959 did not favour this possibility, for the occurrence of wilt on these farms decreased very steeply, from an average of 30% in 1958 to only 6%, which is near what one normally expects in plantations of the tolerant varieties. Although final conclusions would not be justified on this one season's happenings, they do suggest that these exceptional outbreaks may after all prove to be due not to a super-progressive fungus, but to growing conditions on these particular farms which encourage unusually severe wilt most years. Because the summer of 1959 was exceptionally dry, one might suspect that the water retaining properties of the soils of these farms may have had something to do with the severe wilt in previous years.

Do tolerant varieties reduce Verticillium *in the soil?*

A third successive year's records on the farm experiment mentioned in last year's report under this heading show that up to now a remarkably consistent high level of *Verticillium* has been maintained in the soil by the Whitbread's Golding Variety which occupies it ; there has thus been no reduction in the soil population of *Verticillium* over these three years. It was also clear from the records that wilt in this variety has fluctuated greatly on individual hills from year to year.

How does fluctuating wilt affect the tolerant varieties?

Most of the information from our research to date concerns the much more harmful progressive wilt. Thus, for instance, nothing at all is yet known about the effects of fluctuating wilt on the tolerant varieties. This spring an experiment was therefore planted in a Fuggle N garden, severely affected with fluctuating wilt, to get information on this.

Research on resistance mechanisms in tolerant varieties

The waxy substance (suberin) which stops the entry of the fungus into the water-conducting strands in the roots of tolerant varieties, may also promote resistance at an even earlier stage of root invasion

A resistant deposit of suberin in the sheath of cells (the endodermis) surrounding the water-conducting strands was mentioned in the 1957 edition of this review, and this year a similar resistant

thickening was also found to occur in certain tolerant weeds and in one tolerant hop variety in the layer of cells just beneath the outer skin of the roots, i.e. in the region where the invading fungus would first enter into the root tissues. Suberin may therefore prove to be a feature of tolerant plants, operating at both their first and their last lines of defence.

Why wilt may show one year on a hill of a tolerant variety and not in the next

Year to year ' fluctuations ' in wilt symptoms are a well-known feature of progressive wilt in tolerant varieties, and of fluctuating wilt in sensitive ones; they raise the question of the extent to which the fungus invading the woody parts of a hop hill in a year when severe wilting occurs can get directly into the wood of the next year's new growths. This year preliminary work showed that there is in fact very little such direct connexion, the water supply of the new growth coming mainly through the new wood laid down in the roots of stools the same year. It appears therefore that any one season's growth of the infective fungus may to a large extent become ' locked up ' in the wood produced in that year, and more work on this interesting possibility is planned.

Research aimed at direct control by the rapid reduction of soil populations of the progressive fungus

A speedier method for diagnosing a new outbreak as progressive or fluctuating has been found

Using the ' concrete tank ' method of Talboys and Wilson no answer is forthcoming until a year after an outbreak has first been discovered. This year, adapting the softwood cutting ' mist propagation ' method developed with such success by the Department of Hop Research at Wye, tests, set up in a greenhouse under supplementary artificial light, were made in March, and complete answers were available three months later. The completion of a test within the year in which a new outbreak is discovered is therefore now practicable; also the utilization of the winter months for such tests.

Meanwhile work on the alternative microscope method of diagnosis, involving root inoculation with conidia, mentioned last year, is continuing.

Wilt may be spread in waste from machine-picked tolerant varieties

This year a working party, drawn from the Department of Hop Research and the N.A.A.S. at Wye, and ourselves, started to study the extent and size of this probable danger, and how it could best be countered. We have been particularly concerned with experiments to find the minimal programme of heat-treatment necessary to eliminate the *Verticillium* fungus from the bine in such waste, and it has already become clear, unfortunately, that such infected bine is very resistant indeed to this treatment; in fact relatively long exposures at temperatures as high as 50° C are necessary to make such bine innocuous.

Additional evidence this year supports the idea that in bare soil or in soil planted with a resistant grass Verticillium *can travel only in the form of spores (conidia)*

In a glasshouse experiment in which the possibility of dispersal by water-borne spores was precluded, spread by the growing on of fungal threads (mycelium) only occurred when the soil had been planted with a sensitive crop (tomato).

Soil conditions influence the length of time that the fungus can survive there

In unsterilized soil the mycelium of the fungus (its system of ramifying threads or hyphae) was found to be capable of surviving for at least 14 weeks, and, surprisingly, the delicate thin-walled conidia for as long as 5 weeks.

In the experiment, mentioned last year, on speeding up the freeing of soil from *Verticillium*, the fungus was still persisting within diseased hop bine after 3 years under grass cover, and under complete fallow. It has survived best, however, under annual-weed tumbledown.

Virus diseases

A large-scale experiment was set up to discover whether nettlehead is spread through the soil or the air or both

This experiment, which was sited in a plantation of Calcutt's Early Fuggle in which nettlehead was known to be actively spreading, was planted with healthy sets of the same variety either (1) growing in sterilized soil protected from the hop garden soil in polythene containers, (2) planted directly in the garden soil, but with their above-ground growth completely protected from the start in polythene sleeves, or (3) with both root and stem-growths unprotected. This should show in the course of time whether the disease is spreading by some agency active in the soil or in the air, or, if the disease is caused by more than one virus, possibly spreading in both these ways. If the latter is true then grafting a soil-protected to a stem-growth protected plant should produce nettlehead in both.

The search for animal vectors of nettlehead was concentrated this year on leaf and frog hoppers (aerial spread) and nematodes (soil spread)

In the experiments started last year, two test plants which had been infested with a mixed collection of hoppers from plants around an old-established nettlehead outbreak developed nettlehead. These hoppers were found to belong to three species and each of these is now being tested singly as a possible vector.

The work with nematodes was limited for a start to a survey of the soil of five old-established nettlehead sites, but so far only a single specimen of an eelworm related to a species known to transmit plant viruses in the soil has been found.

The drive to discover an indicator plant for split leaf blotch

Unfortunately, hills infected by this disease are frequently devoid of any tell-tale symptoms whatever, and up to the present we have therefore had to rely for diagnosis on grafts to Fuggle which itself is far from completely reliable in this respect. Tests of seedlings of Fuggle as possible indicators were continued this year, but each of the tested six clones proved to be quite inadequate. An attempt to free Fuggle N plants from this virus by heat-treatment was started.

The search for the vector of mosaic

Following consistently negative results with Eriophyid mites, it was decided to retest, on a large scale, the hop damson aphid (*Phorodon humuli*), and transfers of this aphid, collected both from virus-infected *Prunus* spp. and from hops, were made to sensitive hop test plants. The results are awaited.

Summary

Items of special interest to hop growers in the Station's Report of research in 1959 on *Verticillium* wilt and the virus diseases of hops are reviewed and discussed.

PROGRESS IN RESEARCH ON FRUIT CROPS IN 1959

By B. F. SELF

Items of more practical interest in the reviews of research in Part II of this Report have been collected in this article for the information of fruit growers.

Rootstocks

The semi-dwarfing apple rootstock M.26, which produces trees somewhat larger than M.IX, has now been released for distribution to Members (p. 6). In 1958, the time of bud-break of some varieties on this stock was variable and new studies suggest that this trouble was caused by using exceptionally thick rootstocks and budding rather early. It is therefore recommended that M.26 should be budded in August rather than July. The 1959 nursery trees on M.26 compare favourably with those on other stocks.

The yields from the semi-dwarfing plum rootstock trial again show that varieties crop heavily on St. Julien A and Marianna. Unfortunately, this latter stock, unlike St. Julien A, is incompatible with some varieties.

Mist propagation

Work on the propagation of rootstocks shows that softwood cuttings root easily under mist, but that difficulties occur in the subsequent establishment and growth of the rooted shoot (p. 7). Thus the method seems useful mainly for rootstocks that cannot be propagated easily by layering or by hardwood cuttings.

Pruning

Trees pruned by the lighter systems of pruning come into bearing earlier and generally produce a greater total yield (p. 7). The individual fruits on some varieties are, however, smaller than on trees pruned heavily, so where lighter pruning is used, fruit thinning is more necessary. A bulletin on pruning dessert apples appears on p. 122.

Root studies

New work has started on the seasonal development and functioning of the absorbing root systems of fruit plants (p. 7). Certain aspects of the original research undertaken some 20 years ago on root growth, using root observation trenches, are being extended and special attention is being paid to uptake of water and nutrients.

Microscope studies

The microscopical examination of trunks and branches of scion varieties of apple and plum has now started. The ability of the branches to resist breakage has been found to be related to the length of the wood fibres.

Frost damage investigations

Only slight damage occurred on the frost plot and this showed as blemishes on some fruits. Adequate protection from spring frost damage has been obtained in recent years on apples by continuous water sprinkling, arranged to come into operation automatically when the temperature falls to 32° F. This year a duplicate sprinkler was used which did not come into operation until the temperature reached 29° F and this used, as expected, considerably less water (p. 10). The trees under both treatments were protected from frost rings and frost eyes during periods when the minimum temperature reached 28° F in the unsprinkled areas.

Breeding

Over the last 6 years 47,000 apple seedlings have been produced in the search for high quality late flowering varieties that might escape frost damage. This large number has been reduced to some 2,500 by discarding all except those seedlings that leaf out late and show some resistance to scab and mildew. Many of these seedlings are now carrying their first fruit.

Research on the inheritance of resistance to the rubus aphid has resulted in the breeding of

hybrid raspberry seedlings that are resistant to all known strains of the aphid (p. 9). These will now be used as parents for producing resistant commercial varieties which will avoid infection by the important viruses carried by the aphid.

Soft fruit trials

Over 60 varieties and strains of strawberries are maintained in the insect proof glasshouse. In a variety trial comparing the healthiest available clones of the most popular commercial varieties, a selection of Cambridge Favourite, which is infected with a mild virus gave the heaviest crop (p. 8). For the second consecutive year a clone of Talisman, containing a ' latent ' virus, has cropped more heavily than a completely virus-free selection.

Virus diseases are almost certainly the cause of the general decline of loganberries in recent years. The vigour and yield of healthy plants infected from degenerate ones have been reduced (p. 28).

Two thornless loganberry clones, a thornless sport of Bedford Giant blackberry and a virus-tested clone of Thornless Oregon Evergreen blackberry, are being propagated.

Weedkillers

Weedkillers are being increasingly tested in both tree and soft fruits.

CIPC at 1 lb and propham at 6 lb per acre, applied on strawberries in November soon after planting, caused a reduction in the maiden crop of Redgauntlet and Cambridge Favourite (p. 9). Both materials are mainly residual herbicides and kill the weed seedlings as they germinate.

Weeds were successfully controlled, without harmful effects, by simazine at $2\frac{1}{2}$ and 5 lb per acre in November in preliminary trials on black currants and raspberries (p. 9). Simazine is another residual weedkiller and it kills germinating weed seedlings on clean land at the lower rate and established weeds at the higher rate.

Irrigation

The dry summer of 1959 emphasized the benefits of the moisture reserves present in deep soils. Soil depth is clearly one of the most important considerations in assessing the need for irrigation in an orchard.

Drought effects, such as early yellowing of the foliage and premature defoliation, were experienced on the unwatered plots of the irrigation trial at Larkfield for the first time since it started in 1953 (p. 18). Unfortunately, the experimental variety, Laxton's Superb, was in its 'off' year and fruit effects could not be judged adequately. In a collaborative trial at the N.A.A.S. Experimental Horticulture Station at Luddington, irrigated trees of Cox's Orange Pippin growing in grass showed a marked increase in both vegetative growth and fruit size.

Striking effects occurred from watering soft fruits in 1959. Yields of the raspberries Malling Jewel and Malling Exploit and the black currant Amos Black were increased by about a third, mainly due to improved fruit size. (p. 18). There were wide differences in amount and vigour of new growth this season between the watered and the control plots with both these fruits. The full effects of reduced growth on the dry plots should be observed in next year's crop.

The research on irrigation was demonstrated at the Members' Day on 19th November and the report to Members included details of the results.

Soil management

A straw mulch is very effective in conserving summer rainfall. However, in this season with scarcely any summer rain, both raspberries and apples derived little benefit from the mulch.

Severe drying out occurred under grass to a depth of 4 ft by the beginning of August. Drought symptoms were obvious in the grass plots in the manurial trial with Cox's on the very vigorous rootstock M.XII. Although more fruit was borne in 1959 by the trees in the cultivated plots than by those under grass, it is believed that this is a seasonal effect (p. 18). Records over the years since the soil management systems were superimposed on this trial in 1953 show that grassing down has not reduced the total weight of crop where nitrogen has been applied. A severe reduction has, however, occurred in the absence of nitrogen.

Nutrition

Most of the research at East Malling on manuring has so far concerned apples, but a long term manurial trial with pears has now been planted at the N.A.A.S. Experimental Station, Efford (p. 18). This project is sponsored jointly with Long Ashton and it includes nitrogen, phosphorus, and potash treatments at various levels.

A certain amount is known about the response of fruit trees to different rates of nitrogen fertilizer but much less about the timing of the applications. A trial has started at Efford to study this subject (p. 19). Three different forms of nitrogen fertilizer are being used and each is being applied on six separate occasions during the year on dessert apples in grass.

When apple trees were carefully lifted at monthly intervals throughout one season and their total content of nitrogen, phosphorus, potassium, calcium and magnesium determined, some preliminary information was obtained on when these nutrient elements were taken up (p. 21). The results suggested that the trees began to take up most of the elements from the end of April to May, and continued to do so for some months. The uptake of nitrogen began a month earlier.

Magnesium has been known for a long time to be an essential element for plant growth. There has, however, been little evidence, until recently, that magnesium applications on magnesium-deficient trees could increase cropping. In an experiment on dwarf pyramid trees of Edward VII, five post-blossom foliar sprays of 2% magnesium sulphate each year for 5 years have produced a 70% increase in total crop (p. 19). This appears to be due largely to an increase in the number of fruits. It is possible that the prevention of deficiency symptoms on the fruiting spurs early in the season has improved fruit set.

In contrast to this effect of sprays, soil applications of Epsom salt on stoolbeds continue to give only a slight response (p. 19).

Growth studies

Apple trees carrying a heavy crop make less growth than trees prevented from cropping. Although this is common experience there are many important questions about this effect still unanswered. For instance, is the depressing effect of crop on growth strictly proportional to the size of crop ? During what part of the season does the crop have its main effect on growth ? Trials are in progress to study this whole problem.

In one experiment it was found that thinning early, about 10 days after full bloom, resulted in more extension growth and larger fruits (p. 15).

It was observed in studies on leaf development that lightly pruned trees carried a greater number of leaves at the beginning of the season, but by the end of June the heavily pruned trees had more and larger leaves per branch (p. 15). Deblossoming increased leaf number and size, and this increase began early in the season. These differences can also be related to increases in branch diameter.

With some Cox's trees, previously deblossomed annually, 40 fruits were borne to maturity from every 100 blossom trusses compared with only 8 on those allowed to crop each season (p. 15).

A comparison of leaf and root efficiency has been made by altering the proportion of leaf or root on young apple trees and observing where the subsequent growth occurs. Early results indicate that the removal of half the foliage reduced growth more than severing half the root system (p. 14). Both treatments caused compensatory growth of the treated part.

Growers may be interested to read an article on the growth and behaviour of the fruit tree on p. 128.

Carbohydrate reserves

Further work has confirmed that the carbohydrates (sugars, starch, etc.) produced by the leaves are partly used immediately and the surplus stored. Experiments are now in progress to find out what determines the amounts stored as reserves and their subsequent use. Attempts have been made to make trees use up these reserves by shading and defoliation, but although differences in growth were induced, these treatments had no influence on the carbohydrate composition during the growing season (p. 15).

Bacterial diseases

Bacterial canker of cherries has a definite seasonal cycle with a summer leaf phase alternating with a winter branch canker stage. In the past, copper sprays have been used in autumn to protect leaf scars and thus check canker formation, and in spring to prevent infection of young foliage. In recent years considerable improvement in the control of the disease has been achieved by using a series of early autumn Bordeaux sprays to eradicate the bacteria on the leaf surface and thereby reduce the number available for leaf scar infection. Experiments are in progress to improve the recommendations on strength and timing of these sprays.

The study on fire-blight has continued alongside the efforts of the Ministry to stamp it out (p. 23). The susceptibility of a number of varieties has been tested in the glasshouse with special precautions to make it impossible for the disease to spread outside. The pears Williams' Bon Chrétien

and Conference have proved to be more resistant than Laxton's Superb, and Cox's is more resistant than certain North American apples. These results encourage the hope that our main varieties will not be seriously affected by fire-blight. Infections of some ornamental shrubs have been reported by the N.A.A.S. and further tests have shown that the following groups of plants are among those found to be susceptible : *Chaenomeles, Cotoneaster, Pyracantha, Sorbus.*

Laboratory culture tests have failed to reveal any differences between fire-blight found on pear in England and in America (p. 23).

Viruses are probably associated with all forms of life. In addition to the viruses in plants there are some that attack bacteria, known as bacteriophages. These phages are able to kill actively growing bacteria and as each phage can attack only one kind of bacterium, they can be used as a rapid laboratory method for distinguishing bacterial diseases. For example, blackened flower trusses are an early symptom of fire-blight, but similar symptoms can also be produced by another bacterial disease of pears, blossom wilt, which was quite common in 1959 (p. 23). A bacterial culture, originally obtained from the diseased plant, can be tested separately against the phages for fire-blight and blossom wilt and by this method the bacterium can be identified within 24 hours.

Fungal diseases

Further research in the laboratory on the differing resistance of apples and pears to scab has shown that the chief effect of the organic acid, *o*-coumaric acid, on the fungus is in preventing it from sporing (p. 23). It has little effect on the growth of the fungus.

The conditions for infection by certain diseases are still being studied in collaboration with Rothamsted Experimental Station and the Plant Pathology Laboratory, Harpenden, using a Hirst spore trap and a surface wetness recorder (p. 24). Scab ascospores were collected in the traps at East Malling from late March until the end of April, but no further spores were collected after this month although it rained on a number of occasions. Infection periods were recorded and used for the timing of curative sprays in a trial comparing them with protective sprays applied at regular intervals. Nine sprays were required to deal with the recorded infection periods compared with seven sprays for the protective programme. There was only a little scab in 1959 and both systems controlled this equally well.

The series of field experiments to determine the importance of droplet size and volume of lime-sulphur sprays is now concluded. There was little difference in the degree of control of scab and mildew with the concentrations and spray patterns used (p. 26). These results confirm previous observations and this work will be developed further on potted material in the glasshouse.

It was reported in 1958 that a bud-swelling application of DNC petroleum oil reduced the number of overwintering apple mildew infections. It is now clear that both the oil and the DNC chemical are necessary for maximum effect and that the spray was more effective at bud swelling than in the dormant period (p. 24). The spray appears to limit the spread of the mildew fungus in the infected tissues during bud break and may not be functioning as an eradicant spray.

Several varieties of strawberry were inoculated in 1958 with two species of the wilt fungus, *Verticillium dahliae* and *V. albo-atrum*, to assess their susceptibility to these diseases (p. 25). Talisman appears to show high resistance to both fungi and Cambridge Vigour low resistance. It is important to note that *V. albo-atrum*, which causes wilt in hop, can affect strawberry.

Virus diseases

Information is accumulating on the effect of viruses on growth and cropping. In the 1958 Report it was stated that apple mosaic virus was reducing the cropping of two varieties by about 30%. Many virus diseases show no obvious symptoms in fruit trees and some viruses may not have any harmful effect. It is probable that the newly recognized latent virus in apple, which induces symptoms in a species of *Malus*, belongs to this harmless group. The term ' virus-tested ' as applied to our Mother Trees and some rootstocks does not necessarily mean that they are completely free from viruses. However, such material is free of all the viruses known to affect growth or cropping and is the healthiest source of the particular variety or stock available.

The system of heat treatment first used for the inactivation of certain strawberry viruses and subsequently used for top fruits has enabled the plum varieties Victoria and Ontario and the rootstocks Common Plum and Marianna to be freed from certain important viruses (p. 27). When these varieties and stocks have been propagated in sufficient quantity they will be available for distribution.

Fourteen more varieties including the plums Cambridge Gage, Denniston's Superb, Oullins Golden Gage, Marjorie's Seedling and Warwickshire Drooper, the apple Merton Worcester, the cherry Bigarreau de Schrecken, and the pear Merton Pride, were added to the list of Mother Trees for distribution to Members (p. 27).

For some years a disease has been affecting the appearance of plum fruits in orchards. This disease has now been transmitted by grafting to Warwickshire Drooper and is therefore confirmed as a virus (p. 27). It is very similar to a serious disease in Yugoslavia known as ' plum pox '.

A blister canker observed for many years on young Williams' pear trees is now known to be a virus disease (p. 27). This same virus can be carried without symptoms in Beurré Hardy, which is generally used as an intermediate with Williams' and other varieties that are incompatible with quince. The Mother Tree selection of Beurré Hardy, M.201, is free of this virus.

Nematodes and viruses

In 1958 a nematode, since identified as *Xiphinema diversicaudatum*, was recovered from soil around the roots of strawberries suffering from raspberry yellow dwarf (arabis mosaic). This disease is caused by a soil-borne virus. A survey of further sites in 1959 showed that this nematode was usually present where raspberry yellow dwarf occurred. In glasshouse experiments it has been shown that this nematode can transmit the disease through the soil from plant to plant (p. 27). It is much longer than most nematodes, measuring about half a centimetre. Its long spear or stylet is a characteristic of the genus *Xiphinema*, the members of which are known as dagger nematodes. Other species of *Xiphinema* have been known abroad for some years, but it was only recently that *X. index* was shown to be capable of transmitting a virus disease of grapes in the U.S.A. This was the first record of a nematode acting as a vector of a plant virus disease.

Insect pests

Field observations show that during the summer of 1959 only about 6% of the first generation of codling moth caterpillars pupated and developed into a second generation of moths in spite of the warm dry weather. In addition to chemicals used previously, further organo-phosphorus materials and a new carbamate are being tested in the laboratory against codling moth (p. 30).

New infections of the virus disease rubus stunt in a commercial plot of blackberries were reduced by the combined effect of chemical control of leafhoppers by malathion and the removal of virus infected plants (p. 32).

Mites

In a spray trial at the Essex Institute of Agriculture, four chemicals including a summer ovicide and two phosphorus insecticides were used against fruit tree red spider mite (p. 34). A single spray of each applied in late May achieved good control throughout the season on a plot where chlorbenside resistant populations were present in 1958.

An experiment on the effect of modified spray programmes over the last seven years on fruit tree red spider mite and its predators has now been completed. The predator, the black-kneed capsid, was present on some plots and on these kept the mite populations small (p. 30).

Endrin has given good control of black currant gall mite when used after blossom but, unfortunately, it leaves a poisonous residue in the skin of the fruit. Two other chemicals are being compared with endrin against this mite in the hope of finding something as effective but with a less toxic residue (p. 31).

Analysis of residues

Knowledge of the persistence of spray deposits is often required to interpret fully the observed effect of sprays on pests, predators, and diseases in addition to any harmful action on the plant. The question of residues harmful to the consumer must be considered by the research worker as well as the grower.

Residues are analysed by both chemical and biological methods. With the procedure known as bio-assay smaller deposits of certain insecticides can be determined than by chemical tests. The residue is extracted from the leaf or fruit by a solvent which is then evaporated. Small amounts of the pure chemical are placed in similar containers for comparison. Twenty-five fruit flies are placed in each of the tubes. After 24 hours the dead flies are counted and this number can then be related to the amount of the residue present.

Spray damage

A pre-blossom application of phenyl mercury chloride on Cox's caused leaf scorch and splitting of the fruit truss stems. Post-blossom sprays of 0·005% PMC again led to a reduction in the number

of fruitlets formed on several pear varieties. In addition to this damage chlorotic spotting occurred prominently on Conference and Comice.

Although as reported in 1958 the uptake of magnesium is more rapid from sprays of magnesium chloride than those of magnesium sulphate, there is a greater risk of leaf damage with the chloride (p. 36). It is advisable, therefore, to use weak sprays, only, of the chloride.

Experimental design and plant variation

The Statistics Section is responsible for the lay-out of field experiments and assists in the interpretation of the results. As land on the Station is limited as much information as possible must be obtained from the moderate number of trees that can be planted. A plan is designed to suit the particular purpose of each experiment and the information required from it. Some trials will run for many years and allowance must be made for possible changes, such as the addition of further treatments, the thinning of overcrowded trees and the loss of trees through accident or disease.

However carefully experimental trees are grown in the nursery, selected, and planted out, some variation usually occurs in a field trial, even with clonal material on apparently uniform land. The history, cropping and soil management of the land over many years may all have an effect on the trees. The trees to be planted out may not be as uniform as they appear to be when judged by their maiden growth. Where possible the trees are calibrated by recording their growth for a few years after planting before the treatments are applied. It appears that field experiments can be considerably reduced in size at the cost of calculating the effects of all these factors. Some of these calculations are very complex but they can be undertaken with the help of an electronic computor (p. 12).

Summary

Certain aspects of practical interest to fruit growers from the reports of the Research Sections for 1959 are presented in a popular form.

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